HOME OFFICE.

DEPARTMENTAL COMMITTEE ON HUMIDITY AND VENTILATION IN FLAX MILLS AND LINEN FACTORIES.

REPORT

OF THE

DEPARTMENTAL COMMITTEE

ON

HUMIDITY AND VENTILATION IN FLAX MILLS AND LINEN FACTORIES.

REPORT AND APPENDICES.

Presented to Parliament by Command of His Majesty.

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WARRANT OF APPOINTMENT.

I hereby appoint—

COMMANDER SIR HAMILTON FREER-SMITH, R.N., C.S.I. (formerly Superintending Inspector for Dangerous Trades);

PROFESSOR J. E. PETAVEL, F.R.S. (Professor of Engineering in the University of Manchester);

PROFESSOR J. LORRAIN SMITH (Professor of Pathology in the University of Manchester);

MR. G. HERBERT EWART (of Messrs. William Ewart and Son, Limited, Bedford Street, Belfast); and

MR. HENRY CUMMINS (Chairman of the Weavers' and Winders' Trade Union, Lurgan),

to be a Committee to inquire and report what amendment (if any) to the Regulations for the spinning and weaving of flax or tow and the processes incidental thereto is expedient in view of the Report of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds, or on other grounds.

And I further appoint Commander Sir Hamilton Freer-Smith to be Chairman, and Mr. D. R. Wilson, H.M. Inspector of Factories, to be Secretary of the Committee.

R. McKENNA.

Whitehall, 17th July 1912.

DEPARTMENTAL COMMITTEE ON HUMIDITY AND VENTILATION IN FLAX MILLS AND LINEN FACTORIES.

REPORT.

TO THE RIGHT HONOURABLE REGINALD MCKENNA, M.P., HIS MAJESTY'S PRINCIPAL SECRETARY OF STATE FOR THE HOME DEPARTMENT.

SIR, May 1914.

WE have the honour to submit the following Report on the questions referred to us.

The Committee met for the first time in Belfast on the 22nd July 1912. Since then 45 meetings have been held in Belfast, Glasgow, Manchester and London, in addition to numerous conferences between the Chairman, the Members and the Secretary, 31 spinning mills and 26 weaving factories[1] have been visited, and 65 witnesses[2] have been examined. In addition, large scale experiments have been conducted in certain weaving sheds and spinning rooms,[3] and an extensive collection of temperature and humidity data has been obtained by the employment of recording instruments for several months.[4] Finally, a medical investigation, in the course of which some 1,500 observations of body temperatures, pulse, and respiration rates were taken, was conducted on behalf of the Committee by Dr. T. M. Legge, H.M. Medical Inspector of Factories.[5]

Before the present recommendations were made, informal and confidential conferences were held, with your approval, with the following Trade Associations:—

The Flax Spinners' Association,
The Power Loom Manufacturers' Association,
The Power Loom Tenters' Trade Union of Ireland,
The Textile Operatives' Society of Ireland,
The Ulster Weavers' and Winders' Trade Union,
The Portadown Textile Operatives' Society,

and we hope that the careful interchange of opinions on technical points which led to many useful modifications of the original draft, will reduce to a minimum any differences that may subsequently arise in regard to the recommendations accepted by you.

Inquiry was made through the Foreign Office as to the Regulations in force in certain other countries.[6] We desire to express our thanks to the Belgian Government for facilities granted by them for visits to flax spinning mills in Ghent, Dr. Buyse, Medical Inspector of Factories for the district, under whose guidance the visits were paid, and the manufacturers, who not only gave us free entry into their works, but supplied us with information on all points desired. We are specially indebted to the Société Anonyme Linière Gantoise for copies of a very full record of temperatures kept in their rooms during the whole of the summer, a summary of which will be found in the experimental report.

LOCALITY.—The principal centres of the flax industry are Belfast and the North of Ireland, Dundee and Arbroath in Scotland, and (to a less extent) Bridport and Crewkerne in Dorsetshire, but the character of the manufacture differs greatly in each of these districts, and the humid processes, with which our inquiry is chiefly concerned, are practically confined to Ireland and a few factories in England and Scotland.

PREVIOUS LEGISLATION.—The first special reference to flax spinning occurs in s. xix. of the Factory Act of 1844, which requires that in wet spinning rooms, where women, young persons or children are employed, means shall be taken for protecting the workers from being wetted, and when hot water is used, for preventing the escape of steam into the air of the room. This requirement has been re-enacted in subsequent Factory Acts, and still remains in force.[7]

More recently the flax industry has been the subject of two important inquiries.

In 1892 Mr. E. H. Osborn conducted an investigation into the conditions of work in flax mills and linen factories, and into the mortality among textile operatives in

[1] Appendix XIV. [2] Appendix XV. [3] Appendix XII. [4] Appendix X.
[5] Appendix IX. [6] Appendix IV. [7] Factory Act, 1901 (1 Edw. 7, c. 22, s. 76).

the city of Belfast, and this was subsequently extended to include all other flax mills and linen factories in the United Kingdom. In the Report, published in 1894, special attention was drawn to the unsatisfactory conditions prevailing in many of the wet spinning rooms and weaving sheds, and recommendations were made for securing improvement, most of which were embodied in Special Rules prescribed by the Secretary of State on 26th July 1894. In these the following requirements relating to humid rooms occurred :—

1. Establishment of a standard of ventilation in weaving sheds in terms of size of fan per unit of floor space.
2. Limitation of humidity to not less than two degrees difference between dry and wet bulb temperatures.
3. Provision of hygrometers and systematic recording of thermometer readings.
4. Insulation of steam pipes.
5. Provision of splashboards on spinning frames, with a clearance of 4 feet 6 inches or more, and of waterproof aprons for the spinners when the clearance is less.
6. Prevention of escape of steam from troughs.
7. Drainage of floors.

These rules were subsequently modified to some extent, and an amended code was issued on the 18th April 1896, allowing the alternative provision of splashboards for all spinning frames, or of waterproof aprons for the spinners, irrespective of the distance between the frames.

In 1903 a second inquiry was conducted by the Chairman of the present Committee, at that time H.M. Superintending Inspector for Dangerous Trades. His report, which was published in 1904, contained proposals for Regulations extending the provisions of the Special Rules then in force. The original requirements as to the provision of thermometers, recording of readings, permissible limit of humidity, prevention of escape of steam, and draining of floors in wet spinning rooms were retained practically unchanged, but recommendations were made for the following important modifications and additions relating to humid rooms :—

1. Substitution of a carbonic acid standard of ventilation (five volumes per 10,000 in excess of the outside air) for the fan standard then in force.
2. Provision for the supply of pure water in wet spinning troughs and for humidifying purposes.
3. More definite requirements for the insulation of steam pipes based on the corresponding requirement for Cotton Cloth Factories.
4. Compulsory adoption of splashboards in coarse spinning rooms (*i.e.*, where yarns of 50's lea or less are spun).
5. Provision of suitable cloakroom accommodation for operatives in humid rooms.

On the 11th May 1905, the processes of spinning and weaving of flax and tow were certified by the Secretary of State to be dangerous, and draft regulations embodying the above recommendations with certain modifications were issued on the 18th May 1905. The amendments relating to humid rooms included :—

1. Establishment of a standard of ventilation (20 volumes of carbonic acid per 10,000) for rooms in which gas or oil is being used for lighting.
2. Requirement for one set only of thermometers instead of two, with a corresponding reduction in the number of records, and exemption under certain conditions from the necessity of keeping records in rooms in which the difference between the dry and wet bulb temperatures is never less than four degrees Fahrenheit.[1]
3. A definite chemical standard of purity for water to be used for humidifying the air and in wet spinning troughs.
4. Compulsory provision of splashguards on spinning frames of $2\frac{1}{2}$-inch pitch or over (*i.e.*, on spinning frames on which the distance between the vertical axes of the spindles is $2\frac{1}{2}$ inches or more); in the case of other frames either the provision of splashguards, or, as an alternative, the provision of waterproof skirts and bibs of woollen absorbent material for the spinners.

Written objections to these draft regulations were received from 22 occupiers, and although most of these were subsequently withdrawn, a public inquiry was held

[1] At present advantage is taken of this exemption in 15 mills for 62 humid rooms, distributed as follows :—Carding, 3 rooms; Preparing, 40 rooms; Spinning, 18 rooms; Weaving, 1 room.

in November 1905 before Mr. G. A. Bonner, Barrister-at-Law, as Commissioner. Regulations based on his report of the 25th January 1906, were finally made on 6th March 1906. So far as humid rooms are concerned, the following modifications were made in the regulations as originally drafted:—

1. Relaxation of the standard of ventilation from 9 to 12 volumes of carbonic acid per 10,000 in rooms where electric light is being used for lighting.
2. Substitution of $2\frac{3}{4}$-inch pitch for $2\frac{1}{2}$-inch as minimum for frames on which splash guards should be compulsory, with power to the Chief Inspector of Factories to suspend the requirement as to splashguards by certificate,[1] and substitution of "*suitable*" for the words "*woollen absorbent*" as applicable to the bibs. These Regulations still remain in force.[2]

From the outline given above it will be seen that much attention has already been paid to the working conditions in flax mills. At the time of the two inquiries the chief evil to be overcome was doubtless that of dust, and although the excessive heat and humidity in the wet spinning rooms and weaving sheds come in for frequent notice and criticism, the Special Rules and Regulations were presumably aimed chiefly at the elimination of dust in the dry processes, such as roughing, hackling, and preparing, and such provisions as concern the humid rooms relate to efficient ventilation and protection of the operatives from actual moisture rather than to the physiological aspect of the question, the effect on health and comfort of work in a warm moist atmosphere.

CONSTITUTION OF COMMITTEE.—The Chairman, two of the Members and the Secretary have already served on the Departmental Committee appointed in 1907 to consider certain questions relating to humidity and ventilation in Cotton Weaving Sheds. In the present Committee the flax industry has been represented by Mr. G. Herbert Ewart, of Messrs. William Ewart and Sons, Ltd., Belfast, and Mr. Henry Cummins, President of the Lurgan Weavers' Association.

COMPARISON OF FLAX AND COTTON INDUSTRIES.—In many respects the conditions in the manufacture of cotton and of flax differ widely, but on the other hand in both industries the operatives are exposed to moist atmospheres often at very high temperatures, those occurring in flax spinning being generally in excess of those prevailing in the humid processes for cotton.[3]

So far as concerns the feelings of the workers and the possible injury to their health, it might therefore naturally have been expected that the flax operative would be the first to call for any possible measure of relief. In the Report of the Departmental Committee on Humidity and Ventilation of Cotton Weaving Sheds,[4] attention is called to the very strong opinion held by the Lancashire operatives on the question of artificial humidity, and the attitude of that Committee in regard to the agitation for total abolition is fully explained on p. 5 of their First Report. The recommendations made by the Committee for improving the conditions were approved, and are now embodied in Regulations made by the Secretary of State in pursuance of powers conferred on him by the Cotton Cloth Factories Act (1911). Since then a private Bill[5] "To abolish the infusion of steam and other forms of artificial humidity in Cotton Cloth Factories" has been introduced into the House of Commons.

In Ireland, when the early meetings of the present Committee were announced, considerable misapprehension existed as to the objects in view, and the prevalent impression appeared to be that it was the intention of the Committee to apply without change the Regulations for Cotton Cloth Factories to flax spinning and linen weaving and several petitions signed by operatives requesting that existing conditions might continue were received.[6]

The question naturally arises as to why operatives working under practically identical hygienic conditions, and separated by only a few miles of sea should adopt an entirely different attitude towards an inquiry intended, as far as possible, to give them greater comfort in their daily work. A Report that offers no solution to this apparent anomaly would be incomplete.

It must be remembered that in Lancashire the question of the effects of humidity on health, as is shown in the Report of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds,[7] has been under consideration ever since 1882, and has been constantly kept before the workers by the leaders of the various organisations, and the evidence taken by the former Committee was conclusive in

[1] No application for this suspension has been received hitherto. [2] Appendix I.
[3] Appendix X., p. 50. [4] [*Cd.* 4484], 1909, p. 4. [5] [Bill 204, 1913.]
[6] Appendix V. [7] [*Cd.* 4484], 1909, p. 3.

regard to the desire of the cotton operatives for total abolition of artificial humidity, though it was generally conceded that this would involve harder work and less production with a consequent reduction of wages.

In Ireland the workers are less completely organised than in Lancashire. The question of humidity was so little understood that at an early stage of the present inquiry it was thought desirable to draw up and circulate an explanatory memorandum.[1] Communications were subsequently received from workers asking for improvement of conditions as regards moderation of temperature and other matters, but generally pointing out that the present limit of two degrees difference between the dry and wet bulb temperatures is necessary for the weaving of cambrics and similar fine materials. Otherwise lessened production and consequent loss of wages would ensue, and this result under present economic conditions is a very serious consideration.

It must not, however, be supposed that the question of hygiene has been neglected in Ireland. In the matters of general ventilation and especially of methods for collecting and carrying off dust in the dry processes of the flax trade, as well as of the general well-being of the workers, the flax manufacturers in Ireland have met the existing Regulations in a spirit calling for the highest commendation. Indeed, Mr. W. Williams, H.M. Superintending Inspector of Factories, a witness of great experience stated in evidence,[2] "*There is not the faintest doubt that the conditions have been wonderfully improved. I think the generosity of the manufacturers here in dealing with dust has been remarkable. I know of nothing to compare with it in the whole of my experience of factory inspection.*"

HEALTH OF OPERATIVES.—Dr. Legge's Report[3] is based on 1,500 observations on the body temperature of the operatives in wet spinning rooms and humid weaving sheds during the summer of 1912.

The weather was on the whole hotter than that of 1909, during which corresponding observations were made on operatives in cotton weaving sheds. The number of observations taken in 1912 was nearly double that for the 1909 Report and the results are, on these grounds, more conclusive. Temperature observations were taken on 31 males and 84 females. In a considerable number double observations, early and late, were made, and by means of these it is possible to make out the effect of the warm atmosphere in raising the mouth temperature in given cases.

The temperature of the men shows an average rise from 98·4° F. to 98·8° F., while that of the women rises from an average of 98·5° F. to 99·2° F.

When the wet bulb temperatures are taken into account and the body temperatures tabulated in relation to these, it becomes evident not only that there is a general rise in the body temperature of the operative as the wet bulb temperature of the air rises, but also that it is more marked when the wet bulb reaches 75° F. and over. Whereas at a wet bulb temperature of 61°–65° F. of the body temperatures of both males and females 82·4 per cent. are under 99° F.; when the wet bulb is 76°–80° F., 51 per cent. of the males and 19·8 per cent. of the females are under 99° F.; when the wet bulb temperature is 81°–85° F., only 6·6 per cent. of the males and 1·8 per cent. of the females have a body temperature under 99° F.

The instances in which a mouth temperature of 100° F. and over occurred are tabulated, and of these 74·6 per cent. were at wet bulb temperatures of 75° F. and over. The outstanding feature of the table is the greater susceptibility of women, as compared with men, to respond to the influence of the wet bulb temperature.

The average pulse and respiration rates of the persons employed with mouth temperatures of 100° F. or over, were 95·1 and 22·2 respectively. The corresponding figures for the analogous inquiry in cotton weaving sheds in 1909 were 101 and 23. Dr. Legge's conclusion is as follows :—"*Regarding as normal a pulse rate per minute of 72, and respiration rate of 16, the above figures do suggest that continued for hours, day after day, and year after year, the effect would be likely in the long run somewhat to affect health. In other words, persons in an atmosphere where the wet bulb exceeds 75° Fahrenheit, are working under adverse physiological conditions.*"

A short memorandum by one of us on the physiological aspect of this question is appended to the report.[4]

Kata-thermometer.—We are much indebted to Dr. Leonard Hill, F.R.S., who has recently designed an instrument known as the "kata-thermometer" intended primarily for determining the rate of cooling of the human body under varying conditione, and serving as a measure of the comfort enjoyed by workers under different conditions of temperatnre and moisture. Readings were taken by Dr. Hill in five

[1] Appendix VI. [2] Minutes of Evidence, q. 2905. [3] Appendix IX. [4] Appendix VIII.

spinning rooms and four weaving sheds, and his observations together with a detailed description of the instrument are given in his evidence.[1]

He also urges that in heated atmospheres, whether moist or dry, greater comfort can be secured by the use of appliances which will keep the air in continual motion, even where circumstances render it inexpedient to admit more than a limited amount of fresh air. In our opinion manufacturers might with possible advantage and at little cost give efficient trial to Dr. Hill's suggestion. This might be done by small fans placed on the heddle-bars of looms or by fixing blades in suitable places on the revolving shafting.

HUMID PROCESSES.—The humid processes in the flax industry may be classified as those in which humidity of the air is incidental rather than necessary for the purpose of manufacture, and those in which artificial humidity is purposely introduced as an aid to the manufacturing process. The former class comprises yarn dressing, wet spinning and wet twisting, and the latter preparing and weaving.

I. Yarn Dressing.

This consists in the treatment of the warp yarns previously to weaving, and corresponds with sizing or slashing in the cotton industry. The warp yarns are drawn slowly between rollers covered with dressing material consisting of starchy matters and water, and are then dried by being allowed to pass over fans or paddles so placed as to impel a current of hot air on to them. For the purpose of heating the air, steam chests are employed, which raise the temperature of the room, whilst a certain amount of moisture is given off from the drying warps. Usually no records of humidity or hygrometers are kept in these rooms.

The dry bulb temperature is high, often exceeding 100° F., but the small amount of moisture introduced is insufficient to affect appreciably the relative humidity, and the wet bulb temperature seems generally to be below the limit where discomfort would ensue.

The operatives concerned are few in number, chiefly adult men, and the work appears to be light from a physical standpoint.

No special legislation therefore seems to be required for these rooms.

II. Wet Spinning.

Description of Processes.—The wet spinning of flax was invented by a French manufacturer, Philipe de Girard, about 1810, and was first introduced into Ireland in 1828. Previously to that time power-spinning frames had been in use, but coarse yarn only was made, the fine counts having to be spun by hand As has been already stated, the wet spinning of flax is chiefly confined to Ireland, a different and much coarser yarn being made by the dry process in most of the Scottish and English mills.

The object of the wet process is to soften the gummy matter present in the flax fibre, and so to increase its flexibility and tensile strength as to allow it to be drawn out and spun into finer yarn than is possible in the dry process. It consists in allowing the rove from the creel to pass through a trough containing hot water, which softens the fibres before they reach the drawing rollers and spindles.

Occasionally, a modification of the usual wet spinning process is met with, in which cold instead of hot water is used. The rove is not passed through hot water, but is allowed to soak, whilst still on the rove bobbins, in tanks through which a current of cold water runs; by the prolonged action of cold water the fibres become sufficiently pliable to be spun. This process, however, is said to be unsuitable for certain yarns.

Another method of spinning, known as the "*demi-sec*" or "*damp*" process, is in common use for certain classes of yarn. In this the rove, instead of being led through a trough, is passed between rollers, one of which is kept constantly wet by revolving in a narrow gutter containing water. The water used is invariably cold, and neither the temperature nor the humidity in such rooms is ever excessive, but a considerable amount of spray is sometimes thrown off from the spindles, which are usually protected by splash-guards. We recommend that this process be made subject to the same requirements as wet twisting, which is considered later in the report.

Results of Experimental Investigation.—During the present inquiry a special investigation[2] in regard to the temperature and humidity of wet spinning rooms and linen weaving sheds has been carried out on behalf of the Committee, and the recommendations made by us are for the most part based on the results obtained, which, so far as wet spinning rooms are concerned, are here summarised, those for weaving sheds being considered later under the heading of weaving.

[1] Minutes of Evidence (Qq. 3515, *et seq.*). [2] Appendix X.

Unlike linen weaving, flax spinning is almost universally carried on in rooms forming part of a building of four or five storeys, and necessitates the introduction of large quantities of heat into a relatively limited space. Compared with a weaving shed of the same capacity, the heat produced is approximately ten times as great.

The sources of heat are :—

(1.) The power supplied (25 to 30 per cent. of the total).
(2.) Heat radiated from the troughs (45 to 60 per cent.).
(3.) Heat carried by the water spray from the flyers (10 to 20 per cent.).
(4.) Heat radiated from the pipes used to convey steam to the troughs (3 per cent.).
(5.) Bodily heat of the operatives (1 to 2 per cent.).

This heat is lost in the following ways :—

(1.) It passes by conduction through walls, windows, floor and ceiling (5 per cent).
(2.) It is carried away by the outgoing air (20 per cent.)
(3.) It is accounted for by the latent heat of water removed as vapour in the air current (75 per cent.).

Although these subdivisions cannot be regarded as anything but approximate, they justify the general statement—

(a) that a substantial reduction in the heat entering the room can be effected only by better insulation of the troughs, and
(b) that a substantial increase in the heat carried away can be effectively brought about only by more efficient ventilation, for the total heat introduced is so great that the cooling effect of walls and floor becomes comparatively inappreciable.[1]

The continuous temperature records show a marked difference from those obtained in weaving sheds. Instead of the steady rise during working hours and the sharp drop marking meal hours characteristic of weaving sheds, the temperature variation throughout the day is quite erratic, and the only constant feature of the curves is the sharp rise occurring before the beginning of work (caused by the turning on of the steam), which ceases abruptly when the ventilating fans come into operation.

Notwithstanding the fact that the difference between the mean outside temperature in August and that in January was some 18 degrees, the temperature in a given spinning room varies little between summer and winter, the mean dry bulb temperature for all the rooms investigated in Ireland being 80·3° Fahrenheit in summer and 78·2° Fahrenheit in winter.

The temperature of the hottest room was about 28 degrees in excess of the outside temperature, and that of the coolest room 23 degrees, and it seems that for average conditions in a wet-spinning room, the time spent above 75° Fahrenheit wet-bulb temperature would in the summer amount to about 50 per cent. of the working hours.

A special investigation of the ventilation of wet spinning rooms was also made.[2]

Escape of Steam.—The efficient means for preventing the escape of steam from the troughs, required by Regulation 7, are generally adopted and produce the desired result, although the appliances are naturally more efficient in some rooms than in others. We would especially direct attention to the method of local exhaust found in one mill, which not only carries away the steam at the point of origin, but assists in the general ventilation of the room.[3]

Temperature and Humidity.—Our investigations have satisfied us that the conditions in wet spinning rooms may, without detriment to the process of manufacture, be improved in such a manner as to give additional comfort and better conditions to the persons employed. The existing regulations have done much in this respect, and in some mills have been carried out in a most exemplary manner; in others, however, there is ample room for improvement.

It is at present required by Regulation 5 that in wet spinning rooms the difference between the dry and wet bulb temperatures shall be not less than two degrees Fahrenheit, and it may be thought therefore that this small difference is necessary for manufacturing purposes. From the evidence taken by us and our visits to spinning mills, we are satisfied that the work may be carried on without difficulty

[1] The important effect of increased ventilation is clearly shown in Appendix XI. Daily temperature readings taken in a spinning room over two periods, before and after the installation of additional fans, were put at the disposal of the Committee through the kindness of the firm. The average cooling effect was 4 degrees.

[2] Appendix X., p. 84. [3] Ibid., Figs. xlvii. and xlviii.

with a very much wider temperature difference. One manufacturer alone maintained that there is a definite difference approximating to the present legal limit beyond which the spinning of certain yarns is detrimentally affected.

The actual practice can be inferred from the tables,[1] in which the average dry and wet bulb temperatures for practically all spinning rooms in Ireland are given for one month in summer and one month in winter. It will be seen that only one mill in twenty works on an average at the legal limit, all the others being normally considerably drier. In hot weather about a dozen of the mills (in some of which very fine yarns are spun) work with an average difference of 8 degrees or 10 degrees between the wet and dry bulb temperatures.

In August the average dry bulb temperaturs of these spinning rooms is 80·3° F., a few rooms averaging 85° F., and one 89° F. The average wet bulb temperature of the spinning rooms is 75° F., but in some rooms the wet bulb temperature is above 80° F. for the greater part of the time.[2] It is clear, therefore, that in summer the work is frequently carried on at temperatures which must cause great discomfort and, as the medical report suggests, injury to health in the long run. It follows that means should be adopted to reduce the temperature as much as possible.

About half the heat introduced into a spinning room is radiated from the troughs. It appears that if the present wooden troughs were replaced by others properly lagged[3] so as to limit the heat loss, this might be reduced to one-half or one-third of the present amount (corresponding to a reduction of some 4 or 6 degrees in the temperaturs of an average room), and even without alteration to the trough itself, the loss might be substantially decreased by insulating the lid. Further, since the heat lost from the present troughs, in addition to increasing the temperature of the room, represents nearly 2 lbs. of coal per hour per frame, it would appear that the cost of the lagged troughs would be more than balanced by the saving in coal consumption.

The regulation of the temperature of the water is frequently unsatisfactory, and in some mills where automatic steam valves are employed for this purpose, good results have been obtained.[4]

Although, up to the present, the lagging of troughs has not yet gone beyond the laboratory stage of experiment, and the automatic steam valves have only recently begun to be adopted in a few mills, the results so far obtained indicate that there may be great possibilities in both of these methods of reducing the temperature in wet spinning rooms, and we think that employers would find it to their advantage to give them a thorough trial under actual working conditions.

In new mills the stands and passes are usually wide, the ceiling high, the floor well drained, the power transmission efficient and the steam pipes well insulated. Such arrangements tend to reduce the temperature of the room, but the amount of ventilation remains the most important factor; for it can be shown that more than nine-tenths of the heat is carried away by the ventilation current.[5]

Standard of Ventilation.—Various suggestions as to the terms of the standard have been considered. In spinning rooms where the object is to cool the rooms rather than to reduce the moisture or to increase the chemical purity of the air, a carbon dioxide standard of ventilation is unsuitable, since the ventilation that may be necessary is so great as to be incapable of accurate measurement by the determination of the proportion of carbon dioxide. Great difficulty, therefore, presents itself in making specific recommendations. It is impracticable in every instance to require that the temperature of the rooms shall not exceed a given point, since this depends on the temperature outside; nor is it possible to prescribe any given difference between the inside and outside temperatures, since a sudden change of the latter would not immediately affect the former. We are therefore of opinion that whereas at all times ventilation conforming to the present standard of five volumes of carbon dioxide per 10,000 in excess of that in the outside air should be provided, special requirements are called for when the wet bulb temperature reaches 75° F., the point at which according to medical evidence bodily discomfort begins.

At the present time the capacity of the ventilating plants installed in spinning rooms differs considerahly. A few rooms have fans capable of producing 18 changes of air per hour, while in others the artificial ventilation corresponds to three changes or less. These differences have not arisen accidentally, but are in great part due to differencea of construction and equipment of the various rooms. In some of tho older

[1] Appendix X., Tables 17 and 18.
[2] *Ibid.*, Table 17.
[3] For a description of the kind of trough suggested, *see* Appendix X. (p. 96).
[4] Daily temperature readings in a wet spinning room where these have been installed have been kindly supplied by the firm, and are shown in Appendix XI. It appears that since the provision of steam valves the average temperature has fallen 4·7 degrees F.
[5] Appendix X., p. 72.

mills the machinery is very crowded, and in these the air must be changed more frequently in order to lessen the rise of temperature. In fact, as the quantity of heat flowing into a room depends on the amount of machinery installed, and not on the size of the room, it is necessary to indicate the amount of air required to carry away the heat also in terms of the amount of machinery; or to specify that a certain number of cubic feet of fresh air should be introduced each hour for each linear foot of spinning frame installed.

When the wet bulb temperature is in excess of 75° F., we recommend that means should be taken to introduce 1,000 cubic feet of air per hour for every linear foot of trough installed in the room, the ventilation to be so arranged as to ensure that the distribution is uniform throughout the room. Such a requirement would bring about considerable reduction in the temperature and would at all times provide the circulation of air which is so desirable for the comfort of the workers.

Nearly all the flax spinning rooms are at present ventilated by exhaust fans placed in the windows and this system renders accurate measurement of the air flow a matter of some difficulty. In the opinion of some ventilating engineers[1] the distribution by trunks would be preferable, and the adoption of this system would certainly render it easy to check the output of the fans.

A careful analysis of the conditions prevailing in one of the few mills fitted with ducts will be found in the experimental Report.[2] The spinning rooms in this mill are ventilated on the exhaust system, and the air is drawn into the ducts through slots placed immediately above the trough covers. In this way the steam and the hottest air are removed before they can mix with the atmosphere of the room, which remains exceptionally cool and dry. The inlet slots extending along the entire length of the trough cover are the essential feature of this system, and this involves a separate branch duct to each frame and an air trunk running along the length of the frame behind the creels and between the troughs.

The ordinary systems of trunk ventilation do not offer the same advantages, but they secure uniform distribution of the air, which is less easily obtained with the simple exhaust fans. In a weaving shed where a central conditioning plant is used and air at the desired degree of humidity must be distributed evenly over a wide room, a suitable arrangement of ducts is essential. In a spinning room, however, where no conditioning is necessary, the advantage gained by introducing or exhausting the air through openings in a long duct instead of admitting it directly from the windows, which are evenly spaced along the room, is in general less apparent.

We do not, therefore, feel justified in recommending the general introduction of duct systems of ventilation.

In view of the inconvenience of making frequent tests of the air currents produced by window fans, we recommend that a schedule of the output of propeller fans of various sizes be drawn up[3]; and that where the area of the inlet openings is not less than three times the total area of the fans, the output of the fans installed be inferred from the speed of the fan and from the schedule above mentioned. Provided, however, that should the inspector for any reason consider a direct test desirable, the manufacturer should give reasonable facilities for such a test. Provided also that if the occupier of any factory considers that the output of any fan used by him is higher than that specified in the schedule he may submit the fan for testing in a manner and by an authority to be approved by the Chief Inspector of Factories, and the output of that fan as determined by the test shall be then substituted for the output in the schedule.

Construction of New Rooms.—It is pointed out in the experimental report[4] that the construction of wet spinning rooms has an important bearing on the temperature. We accordingly recommend that, subject to the exception stated below, all wet spinning rooms hereafter erected shall conform to the following requirements:—

(a) The minimum height of the room shall be not less than 12 feet.
(b) The width of the room shall not exceed six times the minimum height of the room.
(c) The pitch of the bays shall be not less than 9½ feet.
(d) The width of the main pass shall be not less than 5 feet.
(e) The width of every window shall be not less than the wall space between two windows.

It has, however, been represented to us that in the future spinning rooms may be built on a different system, which would give equally satisfactory conditions but

[1] Minutes of Evidence (Qq. 4405–7, 4506–8).
[2] Appendix X., p. 90.
[3] A draft schedule is appended to the report.
[4] Appendix X., p. 98.

would not be in accordance with these requirements. To meet this we suggest that power be given to the Chief Inspector of Factories to suspend any of these requirements in respect of such a spinning room if he is satisfied that they are unnecessary or impracticable.

Splashguards.—Generally speaking, the condition of the wet spinning rooms seen by us must be described as unsatisfactory. The floors are not kept as clean or as dry as they should be, and extensive accumulations of dirty water are not uncommon. Much can be done to improve matters by more thorough drainage and by greater attention to the condition of the floors, but the really efficient remedy noticed by us is the adoption of splashguards.

In Scotland these are practically universal on wet spinning frames, and in certain mills in Ireland they have been in use for many years. In the Belgian spinning rooms visited by us they are also generally adopted, and we were assured that they would become universal with the introduction of new machinery.

This question has occupied our serious attention, and we have borne in mind the objections raised against the use of splashguards when former inquiries were held. We realise that many workers object to them, chiefly on the ground that they interfere with the process known as "*laying on*," and we are of opinion that whilst splashguards should be provided on all frames of $2\frac{1}{4}$-inch pitch and over, an exemption from their use might be granted for frames where it is shown that owing to the size and speed of the spindles the process of *laying on* could not be carried on without risk of injury to the workers or undue hindrance to the work, but that this exemption should be subject to the wearing of the prescribed protective clothing and the efficient drainage of the floors, and should cease to apply when the necessity for it ceases to exist.

It has been brought to our notice that the requirements contained in Regulation 9 have not been properly observed. It is there laid down that, failing the provision of splashguards, "*waterproof skirts and bibs of suitable material shall be provided by the* " *occupier and worn by the workers.*" The wearing of the bibs, which are intended for the protection of the chest, is therefore a compulsory alternative to the provision of splashguards, but in practice this is almost wholly disregarded, on the grounds that the waterproof material of which the bibs are made prevents free perspiration, and consequently causes discomfort. In our opinion, the regulations as laid down should either be strictly observed, or, if the objections are sound, should be altered to meet them.

We accordingly recommend that the use of splashguards should be made compulsory for all wet spinning frames of $2\frac{1}{4}$-inch pitch and over (except as already provided), and, unless skirts and bibs of suitable material, provided by the occupier, are worn by the workers, for all other frames also.

It is suggested that a standard garment, combining both skirt and bib, and made of a material and according to a pattern approved by the Chief Inspector of Factories, should be adopted, and that it should be put on before the beginning of work and taken off before leaving the mill.

It is further recommended that the present exemption from the use of splashguarde should apply where the width of the stand between the frames, measured from spindle to spindle, is less than $4\frac{1}{2}$ feet,[1] or where other structural difficulties, such as columns in the centre of the stand, arise.

Steam Pipe Coverings.—The existing code (Regulation 8) provides that all steampipes shall be as small and as short as possible and shall be effectively covered with non-conducting material. In Regulation 6 of the Cotton Cloth Factory Regulations more specific requirements are laid down as to the quality of the insulating material and other matters. We recommend that a modified form of the latter shall be applied to wet spinning rooms, and shall come into force after a period of three years. Some amendment is necessary, since it is essential that the main pipe feeding the branch pipes to the troughs shall have a larger diameter than is recognised in the Regulations, and also because covering the small portion of the branch pipe from the point where it divides to serve the troughs on either side of the frame would be attended with inconvenience. We recommend, therefore, that an internal diameter of 3 inches (or, when low pressure exhaust steam is used, 4 inches), shall be allowed for main pipes, and that it should be permissible to leave the part of the branch pipes described above uncovered.

Humidity Records.—Seeing that in wet spinning rooms the principal requirement relating to ventilation comes into force only when the wet bulb temperature reaches

[1] The width of the stands has been measured in 110 spinning rooms and the results are tabulated in Appendix XIII.

75° F., it is necessary that special care should be taken that the management may be informed when this temperature is reached. It is also desirable for administrative purposes that the Inspector on the occasion of his visits should have access to a record of the general condition of the room so far as temperature is concerned. It is accordingly recommended that the present requirement as to keeping records should remain in force, with the exception that the records should be made three times a day, namely between 7 and 8 a.m., 11 and 12 noon, and 4 and 5 p.m., instead of twice a day as at present, and that they should be retained at the factory for a period of two years instead of being forwarded to the Home Office.

Accommodation of Clothing.—The question of clothing accommodation in wet spinning rooms is one of some difficulty. Had such a suggestion been practicable, we should have recommended that suitable cloakrooms be provided for persons employed in wet spinning rooms, but these rooms are situated on storeys one above another, and are approached by staircases, so that the provision of cloakrooms on each floor is in almost every instance impossible. On the ground floor the question of space would generally preclude the erection of cloakrooms of sufficient size for the use of all persons employed, and even if this difficulty were overcome, the loss of time to the workers in using such a room and the strong aversion to losing sight of their clothing, are objections sufficient to render such method undesirable.

The provision of suitable boxes was suggested and considered, but the use of these is open to some objection. Wet clothing taken off and placed in a box will remain wet and in an unfit state to wear on leaving the mill. For this reason and in view of the different facilities available in spinning rooms and their approaches, it only remains to make recommendations of a general character, each occupier being left the option of adopting whatever means he thinks fit, subject to the conditions that the clothing shall not be exposed to the spray from the flyers, or condensed moisture from above, and shall not be in contact with the wall or other damp surface.

In some mills facilities are given by the employers for the spinners to hang up and dry wet clothing in the yarn drying room. Where this is practicable and the workers themselves are willing to avail themselves of it, we think that this method is to be recommended.

III. Wet and Damp Twisting.

In this process the spun yarns are converted into "thread." The frames used for this purpose differ in detail, but the principle of all is the same. Two or more separate yarns are led through a trough of water or are passed between wet rollers and are then twisted together on either flyer or ring bobbins. Cold water only is used, and the humidity introduced into the air is, therefore, very small in amount. Twisting rooms are not usually regarded as humid rooms, and no records are kept, but the temperature appears never to be excessive. On the other hand, a considerable amount of spray is thrown off from the bobbins, especially where coarse yarns and flyer bobbins are used, and splashguards are usually adopted.

We are of opinion, therefore, that, apart from the general provisions as to ventilation, initial temperature, and purity of water, a requirement to the effect that splashguards or other efficient means of preventing the persons employed from being wetted shall be provided and used when necessary, should be applied to wet twisting rooms.

IV. Preparing.

This term comprises all processes by which the "*sliver*" or ribbon of flax is converted into "*rove*" preparatory to spinning. The two chief intermediate processes are known as "*drawing*" and "*roving*."

In these the sliver or rove passes between a series of boxwood rollers which press heavily on the fibres and by friction develop electrical charges of opposite kinds. Electrostatic attraction is thereby set up between the rove or sliver and the rollers, which consequently tend on revolving to carry round with them some of the fibres. To counteract this effect, it is common to introduce into the air a certain amount of moisture, which prevents the separation of an electrical charge. The moisture introduced is small in quantity, being often dispensed with except during very dry climatic conditions, and there seems to be no danger of the wet bulb temperature reaching a point where discomfort would ensue. In addition to preparing rooms proper, artificial humidity is occasionally introduced into carding and winding rooms, but the conditions are precisely those described above and call for no further comment.

We accordingly recommend that, in accordance with the precedent of the latitude allowed by statute to cotton spinning mills,[1] the keeping of humidity records in such rooms shall, in future, be dispensed with, as is now already often done under the latitude allowed by Regulation 9, and that they shall be subject only to the general requirements as to ventilation, initial temperature, limit of humidity, purity of water, keeping of hygrometers, and specification of hygrometers.

V. Weaving.

Description of Process.—The weaving of linen differs little from the weaving of cotton cloth, and is usually carried on in sheds of almost similar construction. The extent to which humidity is introduced varies very much according to the class of linen manufactured, the least amount being used for "damasks" and coarse linens, and the greatest for "cambrics" and similar fine goods.

Results of Experimental Investigation.—The special investigation[2] in regard to the temperature and humidity of linen weaving factories has enabled us to compare the conditions of the linen industry with those of the manufacture of cotton cloth. The fundamental conclusions drawn from similar investigations in the cotton industry[3] are for the most part applicable to the linen industry, and the following is a summary of the results.

The climate of the working districts in the north of Ireland is in summer about one degree cooler, and in winter about one degree warmer, than that of the Lancashire district, and, taking the whole year, the average difference works out at 0·2 degrees (Ireland, 48·0° F.; Lancashire, 48·2° F.). In summer there is more sunshine in Lancashire than in Ireland, but at other seasons the differences are small in this respect. Ireland has 3 inches of rainfall in excess of Lancashire, but the average humidity for the year differs little.

The capacity per operative of the linen and cotton sheds is about the same, but the capacity per loom of the linen shed is about half as much again as the average cotton shed.

The maximum summer temperature of the Irish sheds is about two degrees below that of the cotton sheds, but since the linen sheds work with a difference of about two degrees between the dry and wet bulb temperatures while the Lancashire sheds maintain a difference of about four and a half degrees, the weaving sheds of the two countries have practically the same maximum wet bulb temperatures.

To compare one shed with another as regards temperature, we may adopt the method of subtracting from the maximum shed temperature half the outside mean temperature. When this is done, it will be seen that a more or less constant figure is obtained for any given shed. A shed which gives a high figure will be hotter than a shed with a low figure for any given outside temperature.

Various conditions contribute to determine the hot or cool character of the shed. The sources of heat are :—

1. Power supplied (50 to 70 per cent. of the total).
2. Heat radiated from steam-pipes (15 to 20 per cent.).
3. Bodily heat of operatives (15 to 20 per cent.).
4. Radiant heat of the sun.
5. Accidental sources of heat, such as an adjacent boiler-house.

The heat from these sources raises the temperature of the shed till the thermal outflow balances the inflow; this equilibrium is usually attained at the end of the working day.

The heat is carried away in three ways :—

1. In the air used for ventilation.
2. Heat is absorbed in evaporation of any water used for humidification.
3. It is carried away by conduction through the walls, floor, and roof (75 to 90 per cent.).

The cooling of the shed can be brought about by diminishing the quantity of heat introduced or increasing that carried away.

The power supplied to the looms accounts for one-half to two-thirds of the heat introduced, and therefore any economy of power obtained by improving transmission or by better loom construction will reduce this large source of heat.

[1] Factory Act of 1901, s. 96 (*d*).

[2] Appendix X.

[3] Second Report of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds [Cd. 5566], 1911. Appendix V.

As regards steam pipes, it was shown in the Cotton Weaving Report that by lagging it was easy to reduce the heat introduced by this means to one-fifth of that which the pipe gives off before it is lagged.

The bodily heat of the operatives may contribute one-sixth of the total in a cool shed, but in a hot shed this source is relatively unimportant.

The radiant heat of the sun may account for a rise of six degrees at the end of the day, and it is therefore important that the roofs of all sheds should be whitewashed or otherwise protected, as described elsewhere, during the summer months.

As regards the accidental sources of heat, the power house may be so near the shed as to cause an additional and continuous influx of heat and also an uneven distribution of humidity. There should be an open alley-way between the power house and the shed.

The most effective method of removing heat by the air is to maintain an active ventilation and employ cold water to condition the air; the saturation of the incoming air by this method will, however, not maintain a hot weaving shed at a high percentage of humidity, and when the humidity required is above 70 per cent., some additional means of humidification must be used. The only practical methods are to supersaturate the incoming air with steam or to deliver atomised water into the free air of the shed or into ventilating ducts close to the points where the air enters the shed.

At the present time most linen weaving sheds are humidified by passing the incoming air over hot water, or by steam jets. In the former case, since the incoming air is hot, the ventilation does not cool the shed, and cooling can be obtained only by conduction of heat through walls, floor and roof; in the latter case about two-thirds of the heat is eliminated in this way. The temperature of the shed will therefore depend largely on the external surface available. The difference between the temperature of a shed and that of the outside atmosphere increases from 15 to 24 degrees as the external surface per loom falls from 200 to 100 square feet.

Some interesting facts in relation to the temperature of the shed are obtained from a study of the daily temperature curve. During the course of the investigation a considerable number of weaving sheds were visited by us, and among these eight representative sheds were chosen for special study. In these recording instruments were installed and were kept running for several months; in three sheds continuous records were taken for an entire year. The temperature rises steadily during the entire day and reaches a maximum towards the end of the afternoon. The rise is rapid (two to three degrees per hour) in the morning, and slow (less than one degree per hour) in the afternoon. Similarly the fall of temperature is slow (one degree per hour) during the breakfast hour, but more rapid (three to four degrees per hour) at the end of the afternoon. In the hottest sheds the temperature rises quickly but also falls quickly. Therefore an extension of meal hours would materially reduce the maximum temperatures, especially if arrangements were made to maintain the ventilation during these periods.

The average maximum dry bulb temperature reached daily during the summer was for the sheds investigated 79° F., for the hottest shed 82° F., for the coolest 75° F. From the tables it is seen that during summer the average shed works above 70° F. wet bulb for about 60 per cent. of the time, above 75° F. for about 30 per cent., and above 80° F. for about 5 per cent. The corresponding figures for the hottest shed investigated are 79, 54, and 13 per cent.

Temperature and Humidity.—It has always been maintained by linen manufacturers that a difference of not more than two degrees between the dry and wet bulb temperatures is necessary for the manufacture of the finest fabrics. This statement has the support of the operatives, but the question had apparently never been decided by actual experiment. Seeing that for many years very high temperatures have been reached in linen weaving sheds, it seemed all important to learn whether a wider difference between the temperatures could not be maintained without seriously affecting the work. We are indebted to a leading manufacturer for the results of a series of experiments carried out by him, which enable conclusive deductions to be drawn. The details of the experiments could hardly be published without giving to some extent information which in the interests of the whole trade should not be divulged. We have, however, permission to publish a summary which suffices to indicate the necessity for a high degree of humidity for the efficient weaving of cambrics.[1] These results are confirmed by experiments on a large scale made by the Committee, and we are indebted to the Falls Flax Spinning Co., Ltd., the New

[1] Appendix XII.

Northern Spinning and Weaving Co., Ltd., the Smithfield Weaving Co., Ltd., and Messrs. Spence, Bryson & Co., Ltd., for giving facilities for these to be carried out at no small inconvenience to themselves.[1]

The general conclusion is that for the manufacture of fine linens ($18^{\circ\circ}$ and over[2]) a difference of about two degrees between the dry and wet bulb temperatures must be maintained, even at high temperatures. This is in one sense much to be regretted, for the records taken by the Committee[3] show that in summer the wet bulb temperature frequently exceeds the limit at which bodily discomfort begins, and above which long continued work can hardly fail to be productive of injury to health. This is supported by the results of the medical investigation carried out under the supervision of Dr. Legge.[4]

But, although it appears to be impossible to give to linen weavers the full measure of relief recently granted to weavers of cotton cloth, it is felt nevertheless that much may be done without seriously interfering with efficient work. It will be seen that two serious difficulties have had to be faced. On the one hand, the results of our inquiries and experiments have compelled us to recognise that unless an important industry is interfered with in such a way as to risk loss of trade and its transference to other countries in which no special regulations for flax are in force, with its incidental hardships falling largely on the operative classes, work in a limited number of factories must continue under conditions causing bodily discomfort and possibly in the long run injury to health. On the other hand, the medical evidence, the results of the examination of the operatives actually at work, the evidence of the operatives themselves, and the opinions formed by us during our visits, all point to the fixing of a definite limit of wet bulb temperature at which artificial humidification shall cease.

At first sight a partial remedy seems easy, namely, to require that the weaving of cloth for which a difference of two degrees is necessary should be carried on in separate sheds, and that sheds in which coarser cloth, requiring less humidity, is manufactured, should be subject to the same regulation as cotton weaving sheds, namely, cessation of artificial humidity when the wet bulb temperature reaches 75° F. Inquiry, however, has shown that it is a common practice throughout the trade to manufacture the coarse and fine goods side by side in the shed, each weaver being allotted, when possible, both a coarse and a fine loom to attend to, with the object of equalising the amount of work to be done and the wages to be earned. Further, the vicissitudes of trade and the demands of fashion often determine that a shed in which to-day a certain kind of linen is made, may after the course of a few weeks be utilised chiefly for the manufacture of quite a different class of goods. In these circumstances it will be seen that it would be impossible without great dislocation of trade to lay down a general requirement that the sheds shall be classified in the manner already referred to.

In the course of visits to certain factories in which fine goods were manufactured, it was noticed that the weaving was being satisfactorily carried on with a difference of four degrees and over between the dry and wet bulb temperatures. The question naturally arose as to the reason for this, and the reply given showed that it was due to the fact that "boiled" instead of "green" yarns were being used. It appeared, therefore, that it might be possible for manufacturers to dispense with some of the humidity by boiling their yarns previously to weaving. Inquiry made on these lines, and evidence taken from witnesses familiar with the weaving of both kinds showed, however, that the "boiled" yarns are used for a particular class of cloth, chiefly those where comparatively coarse yarns are woven into a close "sett." "Green" yarns are almost exclusively used in the weaving of cambrics, and could not be replaced by "boiled" yarns without great difficulty in the subsequent bleaching process.[5]

We accordingly recommend that all artificial humidity (except such as is caused by the evaporation of cold water) shall cease when the wet bulb temperature reaches 80° F. In recommending this limit, we fully recognise that for a limited number of hours during the hot days of summer, weaving of cambrics and other fine materials may be carried on under difficulty with a possibility of a less satisfactory output, but we feel that this should be accepted by the trade rather than that work should be continued under conditions causing great discomfort and probably loss of health. Further, it is hoped that in the course of time when improved methods of cooling and humidifying have been brought into use, this small inconvenience may cease to exist, or at any rate be much reduced.

[1] Appendix XII. [2] For the meaning of this term, *see* Appendix VII.
[3] Appendix X., Figs. IX., X., XI. [4] Appendix IX.
[5] "Boiled" yarns are yarns which have been treated in weak boiling alkali, and "green" yarns are those used in the natural state.

Cooling of Humid Sheds.—Whilst, however, we have not felt justified in recommending a lower limit than 80° F. wet bulb, we are of opinion that every effort should be made to keep the wet bulb temperature below 75° F., and with this object we recommend that in every shed in which the wet bulb temperature is liable to exceed 75° F. all reasonably available means to keep down the temperature shall be adopted, and shall be maintained in operation whenever the wet bulb temperature is 75° F. or over.

It is practically impossible to specify in detail the "reasonably available means" to be adopted. Sheds are of such different construction, and so differently situated, that the most suitable means of cooling must be considered for each on its merits. It may, however, be useful to direct attention to the following methods already described in the Second Report† of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds:—

The use of double roofs or insulated roofs,

The spraying of roofs with cold water,

The introduction of air for ventilating purposes from as cool a source as possible,

The passage of incoming air through moistened screens, or treatment of the incoming air by passing through cold water and afterwards distributing through ducts,

but none of these methods will be as efficient as humidification with cold water.

Whereas in cotton weaving sheds the inconvenience involved by the cessation of artificial humidity at a wet bulb temperature of 75° F. is small compared with the relief afforded, in the weaving of linen the circumstances are different, and it has been shown that the cutting off of artificial humidity would render the manufacture of very fine goods a practical impossibility and would add to the difficulty of the manufacture of other goods. It is thought, therefore, that an endeavour should be made to obtain humidity without the additional inconvenience of heat.

Doubts have been expressed as to whether by the substitution of water for steam when the wet bulb temperature reaches 75° F. the necessary humidity for successful weaving could be obtained without inconvenience. Various methods of humidifying by means of atomised water have been devised and are being continually improved; and, in this respect, greater efficiency may doubtless be expected in course of time. In anticipation of this we recommend that where humidity is introduced by cold water only, there should be no temperature limit at which artificial humidity should cease, inasmuch as this system of humidifying can only contribute to the cooling of the shed.

In this connection it may be mentioned that certain "local" humidifiers, *i.e.*, humidifiers which distribute the moisture directly on to the warp threads, have been introduced into Lancashire. It is recommended that these should be given a satisfactory trial in the linen weaving sheds.

Witnesses opposed to any alteration in the existing law in regard to limits of humidity, were agreed that much might be done in the way of cooling the sheds. This opinion is shared by us, and we accordingly recommend that the requirements as laid down in the Regulations for Cotton Cloth Factories[1] as to:—

(1) the covering of steam-pipes (Regulation 6);
(2) the construction of sheds hereafter erected (Regulation 7); and
(3) the white-washing of roofs (Regulation 8);

should apply, with some modifications, to linen weaving sheds.

Steam Pipe Coverings.—It has been pointed out that in many of the weaving sheds, the main pipes, which run at right angles to and supply the branch or jet pipes and are often more than 2 inches in diameter, are installed within the shed and could not be removed without extensive structural alterations. We accordingly recommend that the regulations should be amended so as to admit of a diameter of 3 inches for existing main pipes. Further, in view of the fact that most of the pipes were covered in 1906 when the existing regulations came into force, we suggest that the requirements as to obtaining a certificate of efficiency and the insulation of the hangers should be postponed for three years from the date of the new regulations.

Construction of New Sheds.—A slight modification is suggested in the Regulations as to the construction of new sheds, namely, permitting the orientation of the windows between North-East and North-West, instead of North-East and North-North-West, since it appears that some factories are now in existence in which the shed windows face North-West, and a limitation to North-North-West would interfere with the symmetry of the premises in the event of a new shed being erected.

† [Cd. 5566], 1911.

Whitewashing of Roofs.—In regard to the whitewashing of the roof windows, it has been represented to us that the present exemption clause, applying as it does only to roof windows "*so placed . . . that the direct rays of the sun can never impinge upon " them at any time during any day*" is unnecessarily stringent; we accordingly suggest that the words "*during any day*" should be replaced by "*during working hours.*"

Again, in some weaving sheds the ordinary slates have been replaced by special white tiles composed chiefly of non-conducting material, and it would appear that with the adoption of this method of roof covering, whitewashing the slates might be dispensed with without any loss of efficiency. In other factories it is the practice to spray the roofs with cold water during hot weather, and here the use of whitewash is obviously unnecessary. We therefore recommend that discretionary power should be given to the Inspector for the district to grant an exemption from whitewashing where he is satisfied that other equally satisfactory means are adopted, of which the use of non-conducting white tiles, and the efficient spraying of the roof with water carried out whenever the wet bulb temperature in the shed reaches 75° F., may be considered typical examples.

The questions dealt with in the Report are as regards linen weaving factories comparatively new. It is thought, therefore, that any recommendations made by the Committee should be to some extent tentative. After the experience of a few years, definite conclusions can be arrived at as to the results obtained by better cooling, different systems of humidifying and methods of obtaining humidity by local application which would probably only slightly affect the atmosphere at breathing level. During the next few years it will be open to manufacturers to cool their sheds as much as possible, and to experiment as to the best methods of humidifying, and it may eventually be found possible to prohibit all introduction of artificial humidity (except by cold water) when the wet bulb temperature reaches 75° F.

We are, therefore, of opinion that the question should again be considered after the lapse of five years with a view to giving, if possible, greater relief to the operatives without unduly interfering with the efficiency of the work.

Humidity Records.—In the Report of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds(1), the following account was given of the method then existing of keeping and forwarding of humidity records :—

"For the whole year 1907, 33,590 records of humidity, containing nearly 2,100,000 pairs of (wet and dry bulb) thermometer readings, were received. The reported instances of excessive humidity numbered 1,199, but many were apparent only and were really due to neglect of hygrometers, or error in reading them, or in recording the readings. Approximately there were 1,730 pairs of apparently correct entries for each instance of apparent irregularity. The records have to be made in duplicate (s. 92 (2 c.)).

"The work undertaken at the central office (viz., registration of occupiers, checking receipt of the records, making application for belated records, examinations of the entries, forwarding to the district inspectors the records showing instances of irregular readings or altered particulars as to cubic capacity, &c., and other incidental work) occupies the time of four clerks for one week each per month. This is the equivalent of one clerk's whole time on the work.

"One-quarter of the work is done by a second division clerk, the rest by junior clerks.

"On receipt of a record showing contravention, it is the district inspector's duty to give the statutory notice (s. 95) to the occupiers concerned.

"The particulars of cubic capacity contained in the records have some value, but there is little advantage in repeating them monthly."

These remarks apply with almost equal force to humidity records in the flax industry, and it is accordingly recommended that the procedure proposed and since adopted for cotton weaving sheds, namely :—

"That in order to secure general confidence, the readings of the thermometers be taken jointly by representatives of the employer and employed three times on each day, namely, between seven and eight o'clock and eleven and twelve o'clock in the morning, and between four and five o'clock in the afternoon, and that a statement relating to these readings be entered in a register to be kept at the works, and to be open to examination by H.M. Inspectors of Factories, but that records be sent to the Home Office only when irregularities are found, and that the practical details be settled by conference between official representatives of the Manufacturers' and Operatives' Associations."

should be extended to humid weaving sheds.

It has been brought to our notice that the operative representatives referred to have sometimes failed to take advantage of the requirement in the Cotton Cloth Factory Regulations as to the joint reading of the thermometers, owing to objection to the loss of time and consequent loss of wages involved, and to the risk of incurring the displeasure of superiors by recording irregularities. In regard to the

(1) [Cd. 4484] 1909 (p. 19).

former of these objections, it would seem that a contribution made by the workers and handed over to their representatives as compensation for his loss of wages would, when distributed among the large number of workers employed in the sheds, involve individual amounts so small as to be almost inappreciable. As regards the latter, we find it difficult to believe that a manufacturer or any person in authority would find fault with a worker for fulfilling a legal obligation. In view, however, of these objections, the recommendation now submitted renders the observations by the workers' representative optional, and if the workers are dissatisfied with existing methods and yet fail to take advantage of requirements framed for their benefit, the responsibility rests with them alone.

Accommodation for Clothing.—The recommendation made by the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds and now embodied in the Regulations for Cotton Cloth Factories, namely, that—

> "In every cotton cloth factory in which a suitable and sufficient cloakroom is not provided, suitable and sufficient accommodation within the shed shall be provided for the clothing of all persons employed within a reasonable distance of the place of employment and consisting of a sufficient number of pegs, not less than one for each person employed and not less than 18 inches apart, and of a covering of suitable non-conducting material spaced not less than half an inch from the wall or pillar, and so arranged that no moisture either from above, or from the wall or pillar, can reach the clothing."

seems to have been satisfactorily carried out and to have contributed to the comfort of the cotton operatives. In linen weaving sheds, however, there is often insufficient wall space to admit of the full number of pegs, spaced 18 inches apart, and the following alternatives have been suggested :—

(*a*) pegs spaced 9 inches apart with suitable partitions between them,

(*b*) cords suspended between a pair of looms where the clothing may be exposed to the drying action of air currents, and

(*c*) properly ventilated boxes.

We recommend that any or all of these alternatives should be allowed, subject to the condition that the clothing is adequately protected from damp, grease, oil, and dirt.

Provision of Seats.—It has been represented to us (1) that considerable relief would be given to weavers by the provision of some form of seat, such as are already provided in certain weaving sheds for use during intervals when attention to the looms is not required. The seats must be of a kind that can be easily fixed and removed and that occupy little space, and it has been noticed that a common form is a simple strap or band sufficiently wide suspended between a pair of looms. In our opinion some form of seat should be universally provided in weaving sheds.

GENERAL REQUIREMENTS.—There remain to be considered certain general requirements that are common to both wet spinning rooms and humid weaving sheds.

1. *Ventilation.*—The question whether the carbon dioxide standard of ventilation now in force in cotton cloth factories, namely, eight volumes per 10,000 in excess of that of the outside air, should be applied to humid rooms in flax mills and linen factories, has received our consideration. In practice no difficulty has been found in conforming to the present standard in spinning and (except in a few individual instances) in weaving sheds. Seeing, however, that the exigencies of the trade require an exceptionally high temperature and a high degree of humidity in these sheds, it is thought undesirable to modify the existing requirement except so far as to relax it somewhat when cold water only is used for humidifying with the object of making it easier to attain to the necessary relative humidity and to suspend it altogether during the period of the day affected by the use of gas or oil used for illuminating.

We accordingly recommend that the following standard of ventilation should be prescribed for all humid rooms in flax spinning and linen weaving (except where cold water only is used for humidifying), namely, five volumes of carbon dioxide in 10,000 volumes in excess of that of the outside air (except during the period when it is necessary to use gas or oil for illuminating purposes or before the expiration of the dinner hour on any day when gas or oil has been so used, provided always that the mechanical or other means of ventilation necessary to maintain the legal standard of ventilation required at other times be kept running and in efficient working order) instead of the present absolute standard of nine volumes of carbon dioxide

(1) Minutes of Evidence, Qq. 329–37, 3796–802.

in 10,000. We recommend that in weaving sheds in which cold water only is used for humidifying, the standard should be relaxed to 8 volumes in excess of the outside air.

It will be evident that the standard already recommended for wet spinning rooms when the wet bulb temperature exceeds 75° F. will be far more stringent.

2. *Limit of Humidity.*—The existing code of Flax Regulations requires (Regulation 5) that the permissible degree of humidity in all humid rooms should not exceed that corresponding to a difference between the dry and wet bulb temperatures of two degrees Fahrenheit at all temperatures. This allowance seems to be sufficient for wet spinning and preparing and, generally speaking, for humid weaving. but it has been represented to us that for the manufacture of the finest materials there are times when it is exceeded and yet the weaving conditions are such as to require more humidity in order to satisfy the demands of the weavers. It is understood that this difficulty occurs chiefly in the early morning at low temperatures, and we accordingly recommend that, whilst the present allowance of humidity be retained unchanged, an exemption should be granted for sheds known as "plain" factories in which the number of looms weaving with warp settings of fifteen hundreds(¹) and over is at least one half of the total working looms in the shed, during the first morning hour of employment, subject to the conditions that the dry bulb temperature does not exceed 70° F. or fall below 60° F., and that care is taken that no excessive condensation of moisture occurs.

3. *Lower Limit of Temperature.*—Complaints have been received(²) that the temperature in the early morning in weaving sheds is occasionally very low, owing probably to neglect to put the steam heating pipes into operation. This same point was considered by the former Committee on Cotton Weaving, and their recommendation that the temperature should be not less than 50° F. during working hours after the expiration of half an hour from the beginning of the period of employment, was subsequently embodied in Regulation 5 of the Cotton Cloth Factories Regulations.

We recommend that this requirement be applied without change to all humid weaving sheds, and a similar requirement, namely, that the temperature should be not less than 60° F. after the expiration of one hour after the beginning of the period of employment, to all wet spinning rooms, since in these rooms there is less difficulty in raising the temperature in the early morning.

4. *Prevention of Draughts and* 5. *Purity of Water.*—The existing regulations as to prevention of draughts (Regulation 3) and purity of water used for humidifying and in wet spinning troughs (Regulation 6) appear to have been well observed and to fulfill the objects for which they were intended. We recommend that they be retained unchanged.

6. *Condensation on Roof.*—In some of the rooms and sheds visited a source not only of discomfort but probably also of damage to the material and yarn was noticed by us. Owing to the cooling effect of the roof, the layer of air in contact with it becomes supersaturated with moisture and water is deposited on the ceiling. This continually accumulates until it falls in large drops. To intercept the water it is sometimes the practice to suspend a fabric of absorbent material, known as a "*kite*," between the ceiling and the floor.

In our opinion, where such condensation occurs, this precaution or other efficient means of prevention should be adopted.

7. *Construction of Hygrometers.*—In accordance with the recommendation of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds, the Secretary of State is empowered by the Cotton Cloth Factory Regulations to prescribe a standard hygrometer for use in cotton weaving sheds. A standard hygrometer has been prescribed by Order dated 18th March 1912, and the specification will be found appended to the Report.(³)

We recommend that this provision be extended to humid rooms in the flax trade.

8. *Number of Hygrometers.*—The existing Flax Regulations prescribe (Regulation 4) one hygrometer for each room, irrespective of its size. For spinning rooms, which are usually comparatively small, this allowance is doubtless sufficient, but in

(¹) For the meaning of this term, *see* Appendix VII. (²) Minutes of Evidence, Qq. 2969, 3093, &c. (³) Appendix III.

view of the large capacity of some weaving sheds, we recommond that the present requirement for cotton weaving sheds, namely, that—

> "In every humid shed containing seven hundred looms or less, two hygrometers shall be provided, and in every shed containing more than seven hundred looms one additional hygrometer shall be provided for every five hundred or part of five hundred looms in excess of seven hundred, and the hygrometers shall be fixed in positions to be approved by the inspector."

shall be made applicable to linen weaving sheds.

SUMMARY OF RECOMMENDATIONS.—In our opinion the existing Regulations for the Spinning and Weaving of Flax should, so far as regards humid processes, be amended and extended by the following requirements :—

A.—WET SPINNING ROOMS.

(1) That in every wet spinning room in which the wet bulb temperature is 75° Fahr. or over, the ventilation shall amount to the introduction of at least 1,000 cubic feet of fresh air per hour for every linear foot of trough serving one row of spindles installed in the room, and adequate means shall be taken to ensure that the distribution of air is as uniform as possible, in particular—

(a) the inlet openings (or in the case of a plenum system of ventilation, the outlet openings) shall have an area of not less than three times the total area of the fans, and shall be so placed as to cause no direct draught on the workers ;

(b) the volume of air delivered by each fan shall be assumed to be the volume specified in Schedule I., provided that the fan is being run at the specified speed, and for the purpose of estimating the speed, means shall be provided for the use by an Inspector of a speedometer ;

(c) when both plenum and exhaust fans are used the window openings shall be not less than three times the difference between the areas of the two sets of fans and the volume of air circulated shall be assumed to be the volume specified in Schedule , for one set of fans, or where ducts are provided the volume obtained by measurements of the velocity of flow in the ducts.

(d) if an Inspector deems it advisable to measure the flow of air, the occupier at his request shall furnish him with all reasonable facilities for carrying out a test ;

Provided that if the occupier of any factory is of opinion that the output of any fan used by him is higher than that specified in the schedule, he may submit the fan for test in a manner and by an Authority approved by the Chief Inspector of Factories, and the output of that fan, as determined by the test, shall he then substituted for the output in the schedule.

(2) That Regulation 5 of the existing Code relating to the permissible limit of humidity, namely :—

> The humidity of the atmosphere of any *wet spinning* room shall not at any time be such that the difference between the readings of the wet and dry bulb thermometers is less than 2 degrees,

be applied without change to wet spinning rooms.

(3) That Regulation 9 of the Cotton Cloth Regulations, amended as follows :—

> The arrangements for ventilation shall be such that at no time shall the proportion of carbon dioxide in the air in any part of the shed exceed five parts by volume of carbon dioxide per 10,000 parts of air in excess of the proportion in the outside air at the same time,
>
> Provided that—
>
> (1) during any period in which it is necessary to use gas or oil for lighting purposes ; and
>
> (2) before the end of the dinner-hour on any day in which gas or oil has been so used,
>
> it shall be sufficient compliance with this Regulation if means of ventilation sufficient to secure observance of the above requirement during daylight are maintained in full use and in efficient working order,

be applied to wet spinning rooms (except where otherwise provided).

(4) That Regulation 5 of the Cotton Cloth Factories Regulations, amended as follows :—

> the arrangements shall be such that (1) during working hours the temperature shall not at any time on that day be below *60* degrees, and (2) no person employed shall be exposed to a direct draught from any air inlet or to any draught at a temperature of less than 50 degrees :
>
> Provided that it shall be sufficient compliance with the requirement marked (1) in this Regulation if the heating apparatus be put into operation at the commencement of work, and if the required temperature be maintained after the expiration of *one hour* from the commencement of work.

be applied to all wet spinning rooms.

(5) That Regulation 7 of the existing Code, namely :—

Efficient means shall be adopted to prevent the escape of steam from wet-spinning troughs.

be continued without change.

(6) That Regulation 9 of the existing Code as to splashguards be amended so as to read as follows :—

Efficient splash guards shall be provided and maintained on all wet-spinning frames of $2\frac{1}{4}$-*inch* pitch and over, and on all other wet-spinning frames unless skirts and bibs of suitable material, *and of a pattern approved by the Chief Inspector of Factories*, are provided by the occupier and worn by the workers :

Provided that the requirement as to splashguards shall not apply to any spinning frame while used for the spinning of laid on yarns, for which, owing to the size and speed of the spindles, the process of 'laying on' cannot be carried on without risk of injury to the workers or undue hindrance to the work, subject to the conditions that the prescribed protective clothing is worn by the workers, and that the floors are kept efficiently drained :

Provided *also* that if the Chief Inspector is satisfied with regard to premises in use prior to 30th June 1905, that the structural conditions are such that splashguards cannot conveniently be used, he may suspend the requirement as to splashguards. Such suspension shall only be allowed by certificate in writing, signed by the Chief Inspector, and shall be subject to such conditions as may be stated in the certificate.

(7) That Regulation 8 of the Flax Regulations relating to steam-pipe coverings be replaced by Regulation 6 of the Cotton Cloth Factory Regulations, amended as follows :—

In a *wet spinning room* in which steam pipes are used for the introduction of steam for the purpose of *heating the hot-water troughs* :—

(*a*) the *internal* diameter of *the main* pipe shall not exceed *three* (*or, where exhaust steam at a pressure of not more than* 10 *lbs. per square inch above the atmospheric pressure is used, four*) *inches and of the branch pipes one inch* ;

(*b*) such pipes shall be as short *and as small* as is reasonably practicable ;

(*c*) *the whole of the main pipes and the part of the branch pipes between the main pipes and the T*, shall be effectively covered with insulating material kept in good repair, in such manner that the amount of steam condensed in the covered pipe shall not exceed one-fifth of the amount of steam condensed in the bare pipe under the same conditions ; and there shall be kept attached to the General Register a certificate from the manufacturer of the covering to the effect that a sample of the covering has been tested by an authority approved by the Chief Inspector of Factories and has been found to conform to the above standard ;

(*d*) all hangers supporting such pipes shall be separated from the bare pipes by an efficient insulator not less than half-an-inch in thickness ;

(*e*) the steam pressure shall be as low as practicable, and shall not exceed 70 lbs. per square inch.

Provided that these requirements shall not apply to existing pipes which are already efficiently covered with insulating material in good repair, until after a period of three years from the date of the Regulations.

(8) That Regulation 10 of the existing Code, namely :—

The floor of every wet-spinning room shall be kept in sound condition, and drained so as to prevent retention or accumulation of water,

be continued without alteration.

(9) That adequate means be taken to intercept all moisture, condensed on the ceiling, so as to prevent it from reaching any person employed.

(10) That the present requirement of the Flax Regulations (Regulation 6), relating to the purity of water—

No water shall be used in wet-spinning troughs . . . which is liable to cause injury to the health of the persons employed or to yield effluvia ; and for the purpose of this Regulation any water which absorbs from acid solution of permanganate of potash in four hours at 60 degrees more than 0·5 grain of oxygen per gallon of water, shall be deemed to be liable to cause injury to the health of the persons employed,

be retained unchanged.

(11) That Regulation 4 of the existing Code be amended on the lines of Regulations 3 and 4 of the Cotton Cloth Factory Regulations, as follows :—

In every *wet spinning room one hygrometer* shall be provided and maintained in such positions as may be approved by the Inspector for the District.

* * * * * *

In every *wet spinning room* the readings of the hygrometer . . . . shall be observed on every day on which any workers are employed in the room, between 7 and 8 a.m., between 11 a.m. and 12 noon, and (except on Saturday) between 4 and 5 p.m., *and shall be at once entered on the prescribed form.*

The form shall be hung up near the hygrometer to which it relates, and after being duly filled in, shall be retained at the factory for a period of two years. The entries in the *form* shall be *primâ facie* evidence of the temperature and humidity of the air of the wet spinning room.

* *Provided that so much of this Regulation as relates to keeping of records shall not apply to any room in which the difference of reading between the wet and dry bulb thermometers is never less than 4 degrees after the expiration of one hour from the commencement of work, if notice of intention to work on that system has been given in the prescribed form to the Inspector for the district, and a copy of the notice is kept affixed in the room in which it applies.*

(12) That the hygrometers used in all wet-spinning rooms shall conform to conditions similar to those prescribed by the Secretary of State in the Hygrometers Order of the 18th March 1912.

(13) That in every wet spinning room, unless suitable and sufficient cloak-rooms are provided, suitable and sufficient accommodation shall be provided for the clothing of all persons employed, as near as possible to the place of employment, and so arranged that the clothing is not exposed to the spray from the flyers or condensed moisture from above, and is not in contract with the wall or other damp surface.

(14) That in every wet spinning room hereafter erected—

(a) the height of the room shall not at any point be less than 12 feet;

(b) the width of the room shall not at any point exceed six times the height at the lowest point, except in the case of rooms adequately lighted by windows in the roof;

(c) the pitch of the hays, or the shortest distance between the central points of two adjacent bays shall be not less than 9½ feet;

(d) the width of the main pass measured between the extreme ends of two opposite frames shall be not less than 5 feet;

(e) the width of every window shall be not less than the wall space between two consecutive windows.

Provided that in the case of any wet spinning room about to be constructed on a different system, the occupier may submit the plans to the Chief Inspector of Factories, who may then, by certificate in writing, suspend, in respect of such room, any or all of these requirements if he is satisfied that they are impracticable or unnecessary for ensuring that the room will be equally suitable for use as regards ventilation and lighting and in all other respects.

B.—HUMID WEAVING SHEDS.

(15) That on and after January 1st 1915, in every humid weaving shed, the introduction of all artificial humidity (except such as is caused by the evaporation of cold water) shall cease when the wet bulb temperature reaches 80° F.

(16) That in every humid weaving shed in which the wet bulb temperature is liable to exceed 75° F., all reasonably available means to keep down the temperature shall be adopted, and shall be maintained in operation whenever the wet bulb temperature is 75° F. or over.

(17) That Regulation 5 of the existing Code relating to the permissible limit of humidity be amended as follows:—

The humidity of the atmosphere of any humid shed shall not at any time be such that the difference between the readings of the wet and dry bulb thermometers is less than 2 degrees; *but in the case of sheds, commonly known as plain factories, in which the number of looms weaving with warp settings of fifteen hundreds or over is at least one-half of the total working looms in the shed, this provision shall not apply until after the expiration of one hour after the commencement of work, subject to the following conditions:—*

(a) *the dry bulb temperature shall not at any time during this period exceed 70° F., or fall below* 60 F.;

(b) *adequate means shall be taken to prevent excessive condensation of moisture.*

(18) That Regulation 5 of the Cotton Cloth Factories Regulations, amended as follows—

the arrangements shall be such that (1) during working hours the temperature shall not at any time on that day below 50 degrees, and (2) no person employed shall be exposed to a direct draught from any air inlet or to any draught at a temperature of less than 50 degrees:

Provided that it shall be sufficient compliance with the requirement marked (1) in this Regulation if the heating apparatus be put into operation at the commencement of work, and if the required temperature be maintained after the expiration of half an hour from the commencement of work,

be applied to all humid weaving sheds.

(19) That so much of Regulation 9 of the Cotton Cloth Regulations as applies to humid sheds, amended as follows—

The arrangements for ventilation shall be such that at no time shall the proportion of carbon dioxide in the air in any part of the shed exceed *five (or when the artificial humidity is caused by the*

evaporation of cold water only, eight) parts by volume of carbon dioxide per 10,000 parts of air in excess of the proportion in the outside air at the same time,

Provided that—

(1) during any period in which it is necessary to use gas or oil for lighting purposes; and

(2) before the end of the dinner-hour on any day in which gas or oil has been so used,

it shall be sufficient compliance with this Regulation if means of ventilation sufficient to secure observance of the above requirement during daylight are maintained in full use and in efficient working order,

be applied to humid linen weaving sheds.

(20) That Regulation 8 of the Flax Regulations relating to steam-pipe coverings be amended on the lines of Regulation 6 of the Cotton Cloth Factory Regulations as follows:—

In a humid shed in which steam pipes are used for the introduction of steam for the purpose of artificial humidification of the air—

(*a*) the *internal* diameter of *the main* pipe shall not exceed *three* inches, *and of the branch pipes one inch*; and in the case of *all* pipes hereafter installed *in the shed* the *internal* diameter shall not exceed one inch;

(*b*) such pipes shall be as short *and as small* as is reasonably practicable:

(*c*) such pipes shall be effectively covered with insulating material kept in good repair, in such manner that the amount of steam condensed in the covered pipe shall not exceed one-fifth of the amount of steam condensed in the bare pipe under the same conditions; and there shall be kept attached to the General Register a certificate from the manufacturer of the covering to the effect that a sample of the covering has been tested by an authority approved by the Chief Inspector of Factories and has been found to conform to the above standard;

(*d*) all hangers supporting such pipes shall be separated from the bare pipes by an efficient insulator not less than half-an-inch in thickness;

(*e*) no uncovered jet from such a pipe shall project more than 4½ inches beyond the outer surface of such covering:

(*f*) the steam pressure shall be as low as practicable, and shall not exceed 70 lbs. per square inch.

Provided that paragraphs (*c*), (*d*) *and* (*e*) *shall not apply to existing pipes which are already efficiently covered with insulating material kept in good repair, until after a period of three years from the date of the Regulations.*

(21) That Regulation 8 of the Cotton Cloth Factories Regulations, slightly amended as follows:—

Unless some other method certified by the inspector for the district to be equally satisfactory is adopted, the whole of the outside of the roof . . . . and the . . . . surface of the glass of the roof-windows shall be white-washed every year before the 31st May, and the white-wash shall be effectively maintained until the 15th of September.

Provided that the above requirements of this Regulation, so far as regards roof-windows, may be suspended by certificate in writing from the inspector of the district, if it is shown to his satisfaction that the roof-windows are so placed, or are so shaded by adjacent buildings, that the direct rays of the sun can never impinge upon them *at any time during working hours*; which certificate shall be kept attached to the General Register,

be applied to humid weaving sheds.

(22) That adequate means be taken to intercept all moisture, condensed on the ceiling, so as to prevent it from reaching any person employed.

(23) That the present requirement of the Flax Regulations (Regulation 6), relating to the purity of water—

No water shall be used for producing humidity of the air . . . which is liable to cause injury to the health of the persons employed or to yield effluvia; and for the purpose of this Regulation any water which absorbs from acid solution of permanganate of potash in four hours at 60 degrees more than 0·5 grains of oxygen per gallon of water, shall be deemed to be liable to cause injury to the health of the persons employed,

be retained unchanged.

(24) That Regulation 4 of the existing Code be replaced by Regulations 3 and 4 of the Cotton Cloth Factory Regulations amended as follows:—

In every humid shed two hygrometers, and one additional hygrometer for every 500 or part of 500 looms in excess of 700 looms, shall be provided and maintained in such positions as may be approved by the Inspector for the District.

*   *   *   *   *   *   *

In every humid shed *a representative of the workers may be elected by ballot by the persons employed, and* the readings of each hygrometer provided in pursuance of Regulation 3 shall be observed on every day on which any workers are employed in the shed, jointly by *the* representatives of the occupier and of the persons employed, between 7 and 8 a.m., between 11 a.m. and 12 noon, and (except on Saturday) between 4 and 5 p.m.

The prescribed Humidity Register shall be kept in the factory. If any readings taken as above are such as to indicate contravention of *any provisions in respect of temperature or humidity*, the persons who have taken them shall forthwith enter and sign them in the prescribed Humidity Register, and a copy of each such entry shall also be sent forthwith, in the prescribed form, to the Inspector of the District.

At the end of each week the persons appointed to take the readings shall enter and sign in the prescribed Humidity Register a declaration that during the week the readings have been duly taken by them as required by this Regulation, and that (subject to any exception recorded as above) no readings have been such as to indicate contravention of *any provisions in respect of temperature or humidity.*

If no representative has been appointed by the persons employed, the representative of the occupier shall act alone.

The entries in the Humidity Register shall be *primâ facie* evidence of the temperature and humidity of the air of the humid shed or wet spinning room.

Provided that the part of this Regulation relating to the reading of hygrometers and the keeping of a humidity register shall not apply to any room in which the difference of reading between the wet and dry bulb thermometers is never less than 4 degrees, after the expiration of one hour from the commencement of work, if notice of intention to work on that system has been given in the prescribed form to the Inspector for the district, and a copy of the notice is kept affixed in the room to which it applies.

(25) That the hygrometers used in all humid sheds shall conform to conditions similar to those prescribed by the Secretary of State in the Hygrometers Order of the 18th March 1912.

(26) That in every humid shed erected after 30th June 1905 the present requirement of Regulation 11 of the Flax Regulations as to the provision of clothing accommodation in cloak-rooms ventilated and kept at a suitable temperature, and situated in or near the work-room, be continued without alteration, and the requirements of Regulation 10 of the Cotton Cloth Regulations, amended as followe:—

suitable and sufficient accommodation within the shed shall be provided for the clothing of all persons employed, within a reasonable distance of the place of employment and consisting *wholly or in part of the following arrangements:—*

(*a*) a sufficient number of pegs, not less than one for each person employed and not less than 18 (*or, if completely separated by partitions, 9*) inches apart, and of a covering of suitable non-conducting material spaced not less than ½ an inch from the wall or pillar, *or*

(*b*) *a sufficient number of cords, not less than one for each person employed, suspended between two looms, or*

(*c*) *a sufficient number of suitable boxes, properly ventilated, and not less than one for each person employed,*

so arranged that no moisture either from above or from the wall or pillar, *nor grease, oil, or dirt from the machinery,* can reach the clothing,

be extended to other humid linen weaving sheds.

(27) That seats, straps of adequate width, or other suitable means of enabling every person employed in weaving to rest, be provided in all humid weaving sheds.

(28) That Regulation 7 of the Cotton Cloth Factories Regulations, amended as follows:—

In every *humid shed* hereafter erected—

(*a*) the average height of the shed shall not be less than 14½ feet, nor the height of the valley-gutters from the floor less than 12 feet;

(*b*) the lights shall as far as possible face true North; or if this be impracticable, between North-East and *North-West*;

(*c*) the glass of the lights shall be at an angle of not more than 30 degrees to the vertical, except in the case of flat concrete or brick roofs;

(*d*) the boiler-house and engine-room shall be separated from the shed by an alley-way, not less than 6 feet wide and either open to the outside air or provided with louvre or roof ventilators capable of being opened in summer and of an area equal to one quarter of the floor area of the alley way;

(*e*) no boiler flue shall pass under the shed, or within 6 feet horizontally from the wall of the shed,

Provided that paragraphs (a), (b) and (c) shall not apply to extensions or additions to existing sheds, in which the shafting used is a continuation of that already in position,

be made applicable to humid linen weaving sheds.

C.—ROOMS IN WHICH SPINNING BY THE *DEMI-SEC* OR *DAMP* PROCESS IS CARRIED ON, AND WET AND DAMP TWISTING ROOMS.

(29) That splashguards or other efficient means of preventing the persons employed from being wetted be provided and used when necessary.

(30) That recommendations (3), (10), and (18) be applied without change to these rooms.

D.—OTHER HUMID ROOMS.[1]

(31) That Recommendations (2), (3), (10), so much of (11) as relate to the provision of hygrometers, (12), and (18) be extended to all other humid rooms in flax-spinning and linen-weaving factories.

CONCLUSION.—We desire to express our thanks to all the employers with whom we have been brought in contact for the many facilities offered to us and the help freely given in the conducting of our Inquiry. Our work has also been greatly assisted by the co-operation of the Flax Spinners' and Power Loom Manufacturers' Associations, through whom statistical and general information has been placed at our disposal.

Our thanks are also due to the many witnesses who have attended, often at great personal inconvenience, to give evidence before us.

We wish to recognise the efficient manner in which the medical investigation,[2] organised by Dr. T. M. Legge at our request, was carried out by Dr. W. Massey Burnside of Belfast, Dr. G. Dougan of Portadown, Dr. E. B. Purdon of Belfast, Dr. R. Reid of Whiteabbey, and Dr. G. L. St. George of Lisburn, and we believe that the information set forth in that report will be regarded as very valuable.

We also desire to acknowledge our indebtedness to Mr. C. H. Lander, M.Sc., who supervised the Experimental Inquiry[3] during the whole of the time it was in progress, and to Miss Margaret White, M Sc., who was responsible for the arduous and difficult work of reducing and tabulating the records and other data.

Finally we would express our high appreciation of the valuable services rendered by Mr. Duncan Wilson, our Secretary. Owing to his scientific and technical knowledge, his assistance to the Committee has been of very great value, whilst his tact and courtesy have succeeded in securing the hearty co-operation of all with whom he has been brought in contact.

We have the honour to be, Sir,

Your obedient Servants,

H. P. FREER-SMITH, *Chairman.*
HENRY CUMMINS.
G. H. EWART.
J. E. PETAVEL.
J. LORRAIN SMITH.

DUNCAN R. WILSON,
Secretary.

[1] This term is intended to cover all other rooms in flax mills and linen factories into which artificial humidity is introduced, but does not include yarn-dressing rooms.
[2] Appendix IX. [3] Appendix X.

SCHEDULE.

OUTPUT OF PROPELLER FANS.

Diameter of Fan.	Speed (Revolutions per Minute).	Output (Cubic Feet per Minute.)
ft. ins.		
1 0	1,300	1,040
1 6	850	2,300
2 0	630	4,030
2 6	510	6,400
3 0	425	9,200
4 0	320	16,400

Note.—This schedule is intended merely as a specimen of the type of schedule to be embodied in Regulations, and in view of the efficiency of many modern fans some amendment may be necessary.

APPENDIX I.

PRESENT REGULATIONS, DATED FEBRUARY 26, 1906, FOR THE SPINNING AND WEAVING OF FLAX AND TOW, &c.

Whereas the processes of spinning and weaving flax and tow and the processes incidental thereto have been certified in pursuance of Section 79 of the Factory and Workshop Act, 1901, to be dangerous.—

I hereby in pursuance of the powers conferred on me by that Act make the following Regulations, and direct that they shall apply to all factories in which the processes named above are carried on, and to all workshops in which the processes of roughing, sorting, or hand-hackling of flax or tow are carried on.

These Regulations shall come into force on the 1st day of February 1907.

Provided that in the case of all rooms in which roughing or hand-hackling is now carried on, and in which there is respectively (*a*) no system of local mechanical exhaust ventilation, or (*b*) no artificial means of regulating the temperature, Regulations 2 and 3 respectively shall not come into force until the 1st day of February 1908.

Definitions.

In these Regulations—

"Degrees" means degrees on the Fahrenheit scale.

"Roughing, sorting, hand-hackling, machine-hackling, carding, and preparing" mean those processes in the manufacture of flax or tow.

It shall be the duty of the occupier to observe Part I. of these Regulations. It shall be the duty of all persons employed to observe Part II. of these Regulations.

PART I.

Duties of Occupiers.

1. In every room in which persons are employed the arrangements shall be such that during working hours the proportion of carbonic acid in the air of the room shall not exceed 20 volumes per 10,000 volumes of air at any time when gas or oil is used for lighting (or within one hour thereafter) or 12 volumes per 10,000 when electric light is used (or within one hour thereafter) or 9 volumes per 10,000 at any other time.

Provided that it shall be a sufficient compliance with this Regulation if the proportion of cabonic acid in air of the room does not exceed that of the air outside by more than 5 volumes per 10,000 volumes of air.

2. In every room in which roughing, sorting, or hand-hackling is carried on, and in every room in which machine-hackling, carding, or preparing is carried on, and in which dust is generated and inhaled to an extent likely to cause injury to the health of the workers, efficient exhaust and inlet ventilation shall be provided to secure that the dust is drawn away from the workers at, or as near as reasonably possible to, the point at which it is generated.

For the purposes of this Regulation, the exhaust ventilation in the case of hand-hackling, roughing, or sorting shall not be deemed to be efficient if the exhaust opening at the back of the hackling pins measures less than 4 inches across in any direction, or has a sectional area of less than 50 square inches, or if the linear velocity of the draught passing through it is less than 400 feet per minute at any point within a sectional area of 50 square inches.

3. In every room in which hand-hackling, roughing, sorting, machine-hackling, carding, or preparing is carried on, an accurate thermometer shall be kept affixed; and the arrangements shall be such that the temperature of the room shall not at any time during working hours where hand-hackling, roughing, or machine-hackling is carried on, fall below 50 degrees, or where sorting, carding, or preparing is carried on below 55 degrees; and that no person employed shall be exposed to a direct draught from any air inlet, or to any draught at a temperature of less than 50 degrees.

Provided that it shall be a sufficient compliance with this Regulation if the heating apparatus be put into operation at the commencement of work, and if the required temperature be maintained after the expiration of one hour from the commencement of work.

4. In every room in which wet-spinning is carried on, or in which artificial humidity of air is produced in aid of manufacture, a set of standardised wet and dry bulb thermometers shall be kept affixed in the centre of the room or in such other position as may be directed by the Inspector of the district by notice in writing, and shall be maintained in correct working order.

Each of the above thermometers shall be read between 10 and 11 a.m. on every day that any person is employed in the room, and again between 3 and 4 p.m. on every day that any person is employed in the room after 1 p.m., and each reading shall be at once entered on the prescribed form.

The form shall be hung up near the thermometers to which it relates, and shall be forwarded, duly filled in, at the end of each calendar month to the Inspector of the district. Provided that this Part of this regulation shall not apply to any room in which the difference of reading between the wet and dry bulb thermometers is never less than 4 degrees, if notice of intention to work on that system has been given in the prescribed form to the Inspector for the district, and a copy of the notice is kept affixed in the room to which it applies.

5. The humidity of the atmosphere of any room to which Regulation 4 applies shall not at any time be such that the difference between the readings of the wet and dry bulb thermometers is less than 2 degrees.

6. No water shall be used for producing humidity of the air, or in wet-spinning trough, which is liable to cause injury to the health of the perspons employed or to yield effluvia; and for the purpose of this Regulation any water which absorbs from acid solution of permanganate of potash in four hours at 60 degrees more than 0·5 grain of oxygen per gallon of water, shall be deemed to be liable to cause injury to the health of the person employed.

7. Efficient means shall be adopted to prevent the escape of steam from wet-spinning troughs.

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8. The pipes used for the introduction of steam into any room in which the temperature exceeds 70 degrees or for heating the water in any wet-spinning trough, shall, so far as they are within the room and not covered by water, be as small in diameter and as limited in length as is reasonably practicable, and shall be effectively covered with non-conducting material.

9. Efficient splash guards shall be provided and maintained on all wet-spinning frames of $2\frac{1}{4}$ inch pitch and over, and on all other wet-spinning frames unless waterproof skirts, and bibs of suitable material, are provided by the occupier and worn by the workers.

Provided that if the Chief Inspector is satisfied with regard to premises in use prior to 30th June 1905, that the structural conditions are such that splash guards cannot conveniently be used, he may suspend the requirement as to splash guards. Such suspension shall only be allowed by certificate in writing, signed by the Chief Inspector, and shall be subject to such conditions as may be stated in the certificate

10. The floor of every wet-spinning room shall be kept in sound condition, and drained so as to prevent retention or accumulation of water.

11. There shall be provided for all persons employed in any room in which wet-spinning is carried on, or in which artificial humidity of air is produced in aid of manufacture, suitable and convenient accommodation in which to keep the clothing taken off before starting work, and in the case of a building erected after 30th June 1905, in which the difference between the readings of the wet and dry bulb thermometers is at any time less than 4 degrees, such accommodation shall be provided in cloak-rooms ventilated and kept at a suitable temperature and situated in or near the workrooms in question

12. Suitable and efficient respirators shall be provided for the use of the persons employed in machine-hackling, preparing, and carding.

PART II.

Duties of Persons employed.

13. All persons employed on wet-spinning frames without efficient splash guards, shall wear the skirts and bibs provided by the occupier in pursuance of Regulation 9.

14. No person shall in any way interfere, without the concurrence of the occupier or manager, with the means and appliances provided for ventilation, or for the removal of dust, or for the other purposes of these Regulations.

H. J. Gladstone,
One of His Majesty's Principal
Secretaries of State.

Home Office,
Whitehall.
26th February 1906.

APPENDIX II.

PRESENT REGULATIONS, DATED DECEMBER 21, 1911, FOR COTTON CLOTH FACTORIES.

In pursuance of section 1 of the Factory and Workshop (Cotton Cloth Factories) Act, 1911, I hereby make the following Regulations, and direct that they shall apply, in substitution for sections 90, 91, 92, and 94, and Schedule IV. of the Factory and Workshop Act, 1901, to all factories in which is carried on the weaving of cotton cloth.

These Regulations shall come into force on 1st April 1912, provided that paragraphs (*c*), (*d*), (*e*) and (*f*) of Regulation 6 shall not come into force until 1st June 1912.

Provided further that the Chief Inspector of Factories may by certificate in writing suspend the operation of Regulation 1 (*a*) in respect of any *humid shed* for a period not exceeding two years from 1st April 1912, if satisfied, after an inquiry at which the occupier and persons employed shall be heard, that all reasonably available means to keep down the temperature have been adopted, and that by reason of the circumstances of that *humid shed* it is not all times practicable, nothwithstanding the full use of such means, to prevent without cessation of *artificial humidification*, the wet-bulb reading of the *hygrometer* from exceeding 75 *degrees*. Any such certificate shall be subject to the condition that the arrangements for cooling the shed shall be kept in efficient working order, and used whenever necessary, and in the event of any contravention of this condition the certificate may at any time be revoked by notice in writing from the Chief Inspector of Factories.

Definitions.

For the purposes of these Regulations,—

Humid shed means any room in which the weaving of cotton cloth is carried on with aid of *artificial humidification.*

Artificial humidification means humidification of the air of a room by any artificial means whatsoever, except the use of gas or oil for lighting purposes only. Provided that in a room in which there are no distributing pipes or ducts, the introduction of air directly from the open air outside through mats or cloths moistened with cold water shall not, if adopted solely at times when the temperature of the room is 70 *degrees* or more, be deemed to be *artificial humidification.*

Dry shed means any room, other than a *humid shed*, in which the weaving of cotton cloth is carried on.

Degrees (of temperature) means degrees on the Fahrenheit scale.

Hygrometer means an accurate wet-and-dry-bulb *hygrometer*, conforming to such conditions, as regards construction and maintenance, as the Secretary of State may prescribe by order.*

* *See* Appendix III.

Regulations.

1. There shall be no *artificial humidification* in any *humid shed*—
   (a) at any time when the wet-bulb reading of the *hygrometer* exceeds 75 *degrees*, or
   (b) at any time when the wet-bulb reading of the *hygrometer* is higher than that specified in the Schedule of this Order in relation to the dry-bulb reading of the *hygrometer* at that time, or, as regards a dry-bulb reading intermediate between any two dry-bulb readings indicated consecutively in the Schedule, when the dry-bulb reading does not exceed the wet-bulb reading to the extent indicated in relation to the lower of those two dry-bulb readings; or
   (c) at any time, after the first half-hour of employment in any day, when the dry-bulb reading of the *hygrometer* is below 50 *degrees*; or
   (d) at any time, within the first half-hour of employment on any day, when the wet-bulb reading of the *hygrometer* is less than 2 *degrees* below the dry-bulb reading.

2. No water which is liable to cause injury to the health of the persons employed, or to yield effluvia, shall be used for *artificial humidification*, and for the purpose of this Regulation any water which absorbs from acid solution of permanganate of potash in four hours at 60 *degrees* more than 0·5 grain of oxygen per gallon of water, shall be deemed to be liable to cause injury to the health of the persons employed.

3. In each *humid shed* two *hygrometers*, and one additional *hygrometer* for every 500 or part of 500 looms in excess of 700 looms, shall be provided and maintained, in such positions as may be approved by the Inspector of the district.

A copy of the Schedule appended to this Order shall be kept affixed near to each *hygrometer* provided in pursuance of this Regulation.

4. In every *humid shed* the readings of each *hygrometer* provided in pursuance of Regulation 3 shall be observed on every day on which any workers are employed in the shed, jointly by representatives of the occupier and of the persons employed, between 7 and 8 a.m., between 11 a.m. and 12 noon, and (except on Saturday) between 4 and 5 p.m.

The prescribed Humidity Register shall be kept in the factory. If any readings taken as above are such as to indicate contravention of Regulation 1 or Regulation 5, the persons who have taken them shall forthwith enter and sign them in the prescribed Humidity Register, and a copy of each such entry shall also be sent forthwith, in the prescribed form, to the Inspector of the District.

At the end of each week the persons appointed to take the readings shall enter and sign in the prescribed Humidity Register a declaration that during the week the readings have been duly taken by them as required by this Regulation, and that (subject to any exception recorded as above) no readings have been such as to indicate contravention of Regulation 1 or Regulation 5.

The entries in the Humidity Register shall be *primâ facie* evidence of the temperature and humidity of the air of the *humid shed*.

5. In every *dry shed* and in every *humid shed* the arrangements shall be such that (1) during working hours the temperature shall not at any time on that day be below 50 *degrees*, and (2) no person employed shall be exposed to a direct draught from any air inlet, or to any draught at a temperature of less than 50 *degrees*.

Provided that it shall be sufficient compliance with the requirement marked (1) in this Regulation if the heating apparatus be put into operation at the commencement of work, and if the required temperature be maintained after the expiration of half-an-hour from the commencement of work.

In a tenement factory it shall be the duty of the owner to provide and maintain the arrangements required for the purpose of the requirement marked (1) in this Regulation.

6. In a *humid shed* in which steam pipes are used for the introduction of steam for the purpose of *artificial humidification* of the air—
   (a) the diameter of such pipes shall not exceed two inches; and in the case of pipes hereafter installed the diameter shall not exceed one inch;
   (b) such pipes shall be as short as is reasonably practicable;
   (c) such pipes shall be effectively covered with insulating material kept in good repair, in such manner that the amount of steam condensed in the covered pipe shall not exceed one-fifth of the amount of steam condensed in the bare pipe under the same conditions; and there shall be kept attached to the General Register a certificate from the manufacturer of the covering to the effect that a sample of the covering has been tested by an authority approved by the Chief Inspector of Factories and has been found to conform to the above standard;
   (d) all hangers supporting such pipes shall be separated from the bare pipes by an efficient insulator not less than half-an-inch in thickness;
   (e) no uncovered jet from such a pipe shall project more than $4\frac{1}{2}$ inches beyond the outer surface of such covering;
   (f) the steam pressure shall be as low as practicable, and shall not exceed 70 lbs. per square inch.

7. In every *humid shed* hereafter erected—
   (a) the average height of the shed shall not be less than $14\frac{1}{2}$ feet, nor the height of the valley-gutters from the floor less than 12 feet;
   (b) the lights shall as far as possible face true North; or if this be impracticable, between North-East and North-North-West;
   (c) the glass of the lights shall be at an angle of not more than 30 degrees to the vertical, except in the case of flat concrete or brick roofs;
   (d) the boiler-house and engine-room shall be separated from the shed by an alley-way, not less than 6 feet wide and either open to the outside air or provided with louvre or roof ventilators capable of being opened in summer and of an area equal to one quarter of the floor area of the alley-way;
   (e) no boiler flue shall pass under the shed, or within 6 feet horizontally from the wall of the shed.

8. In every *humid shed* and in every *dry shed* the whole of the outside of the roof (windows excepted) and the inside surface of the glass of the roof-windows shall be white-washed every year before the 31st May, and the white-wash shall be effectively maintained until the 15th of September.

Provided that the above requirements of this Regulation, so far as regards roof-windows, may be suspended by certificate in writing from the Inspector of the District, if it is shown to his satisfaction that the roof-windows are so placed, or are so shaded by adjacent buildings, that the direct rays of the sun can never impinge upon them at any time during any day; which certificate shall be kept attached to the General Register.

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9. In every *humid shed* and in every *dry shed* the arrangements for ventilation shall be such that at no time during working hours shall the proportion of carbon dioxide in the air in any part of the shed exceed the limit specified below for that shed, namely,—

for *humid sheds* eight { parts by volume of carbon dioxide per 10,000 parts of air in excess of the
for *dry sheds* eleven { proportion in the outside air at the time.

Provided that—

(1) during any period in which it is necessary to use gas or oil for lighting purposes, and

(2) before the end of the dinner-hour on any day in which gas or oil has been so used,

it shall be sufficient compliance with this Regulation if means of ventilation sufficient to secure observance of the above requirement during daylight are maintained in full use and in efficient working order.

10. In every *humid shed* erected after 2nd February 1898, sufficient and suitable cloak-room or cloak-rooms shall be provided for the use of all persons employed therein, and shall be ventilated and kept at a suitable temperature.

In every *humid shed* and *dry shed* to which the above provision does not apply and in which a suitable and sufficient cloak-room is not provided, suitable and sufficient accommodation within the shed shall be provided for the clothing of all persons employed, within a reasonable distance of the place of employment and consisting of a sufficient number of pegs, not less than one for each person employed and not less than eighteen inches apart, and of a covering of suitable non-conducting material spaced not less than half-an-inch from the wall or pillar and so arranged that no moisture either from above, or from the wall or pillar, can reach the clothing.

R. McKenna,
One of His Majesty's Principal Secretaries of State.

Home Office, Whitehall.
21st December 1911.

Schedule.

HUMIDITY TABLE, FOR THE PURPOSES OF REGULATION 1.

Dry-Bulb Readings	Wet-Bulb Readings.	Dry-Bulb Readings.	Wet-Bulb Readings.	Dry-Bulb Readings.	Wet-Bulb Readings.
(1.)	(2.)	(1.)	(2.)	(1.)	(2.)
50°	48°	61°	59°	72°	69°
51°	49°	62°	60°	73°	70°
52°	50°	63°	61°	74°	70·5°
53°	51°	64°	62°	75°	71·5°
54°	52°	65°	63°	76°	72°
55°	53°	66°	64°	77°	73°
56°	54°	67°	65°	78°	73·5°
57°	55°	68°	66°	79°	74·5°
58°	56°	69°	67°	80°	75·0°
59°	57°	70°	68°		
60°	58°	71°	68·5°		

APPENDIX III.

ORDER, DATED 18TH MARCH 1912, AS TO HYGROMETERS USED IN COTTON CLOTH FACTORIES, MADE IN PURSUANCE OF THE REGULATIONS FOR COTTON CLOTH FACTORIES.

In pursuance of the above Regulations I hereby prescribe the following conditions as regards the construction and maintenance of hygrometers :—

Provided that the Inspector of this district may by certificate in writing defer until 1st April 1914, the application of Conditions 2 (*a*, *b*, *c*) and 3 to any hygrometer furnished with a certificate from the National Physical Laboratory of date not earlier than 1st January 1910; which certificate shall be kept attached to the Humidity Register.

1.—(*a*) Each hygrometer shall comprise two mercurial thermometers, respectively wet-bulb and dry-bulb, of similar construction, and equal in dimensions, scale, and divisions of scale. They shall be mounted on a frame, with a suitable reservoir containing water.

(*b*) The wet-bulb shall be closely covered with a single layer of muslin, kept wet by means of a wick attached to it and dipping into the water in the reservoir. The muslin covering and the wick shall be suitable for the purpose, clean, and free from size or grease.

2. With regard to each thermometer as above, whether wet-bulb or dry-bulb :—

(*a*) The bulb shall be spherical, and not less than two-fifths nor more than three-fifths of an inch in diameter.

(*b*) The bore of the stem shall be such that the position of the top of the mercury column shall be readily distinguishable at a distance of four feet.

(*c*) The scale from 45° to 85° shall extend over not less than 5 inches, beginning not less than 1½ inches from the top of the bulb. Each degree and half-degree, between 45° and 85°, shall be clearly marked on the stem by means of horizontal lines, which shall be shorter for half-degrees than for whole degrees, and shall be readily distinguishable at a distance of two feet.

(*d*) The markings as above shall be accurate; that is to say, at no temperature between 45° and 85° shall the indicated reading be in error by more than two-tenths of a degree.

(e) A distinctive number shall be indelibly marked upon the thermometer.

(f) A dated certificate of examination of the thermometer, and of its compliance with Condition 2, specifying its distinctive number above, from the National Physical Laboratory or other authority approved by the Chief Inspector of Factories, shall be kept attached to the Humidity Register. If an Inspector gives notice in writing that a thermometer is not accurate, it shall not after one month from the date of such notice be deemed to be accurate unless and until it has been re-examined as above, and a fresh certificate obtained, which certificate shall be kept attached to the Humidity Register.

(g) The construction shall be such that the thermometer may be exposed without injury to a temperature of 110°.

3. Each hygrometer shall be so mounted that—

(a) No part of the wet-bulb shall be within 3½ inches from the dry-bulb or within 3 inches from the surface of the water in the reservoir, and the water reservoir shall be below it, on the side of it away from the dry-bulb.

(b) The bulb of each thermometer shall be freely exposed on all sides to the air of the room.

(c) The corresponding points of the two thermometers shall be on the same level.

There shall be marked on the frame of each hygrometer, in such manner as to be readily distinguishable at a distance of six feet

(d) The words "Wet" and "Dry," respectively over (or near to) the wet-bulb and dry-bulb thermometers; and

(e) The temperatures of 50°, 60°, 70°, 80°, and 90°, by horizontal lines and figures; and

(f) The temperatures of 45°, 55°, 65°, 75° and 85°, by horizontal lines, shorter than those marked in pursuance of Regulation 3 (e); except that for the wet-bulb thermometer the temperature of 75° shall be conspicuously marked by an arrow or similar distinctive device.

4. Each hygrometer shall be maintained at all times during the period of employment in efficient working order, so as to give accurate indications; and in particular,

(a) The wick and the muslin covering of the wet-bulb shall be renewed once a week.

(b) The reservoir shall be filled with distilled water or pure rain water, which shall be completely renewed once a day

(c) No water shall be placed in the reservoir, or applied directly to the wick or covering, during the period of employment.

5. No hygrometer shall be affixed to a wall, pillar or other surface, unless protected therefrom by wood or other non-conducting material at least half an inch in thickness and distant at least one inch from the bulb of each thermometer

Home Office, Whitehall,
18th March, 1912.

R. McKenna,
One of His Majesty's Principal
Secretaries of State.

APPENDIX IV.

Result of Inquiry as to Regulations and Conditions in Foreign Countries.

Application was made through the Foreign Office to the Governments of Austria, Belgium, France, Germany, Russia and the United States of America, for certain information in regard to the practice and working conditions in flax spinning and linen weaving. The questions propounded with a summary of the replies received are given below:—

(1) *Are there any special regulations in force for the spinning and weaving of flax, especially as regards the humid processes?*

Austria.—No special regulations are in force, but the inspector has general powers to require adequate protection for the workers, where the conditions appear injurious.

Belgium.—The same.

France.—A special provision relating to flax spinning is in force by Decree of 13th May 1893, by which the employment of children under 18 and women is prohibited in rooms where the floors are not properly drained, on account of the injurious effect of the humidity on the health of the workers. Efficient removal of steam from the troughs is required in general terms by Decree of 29th November 1904.

Germany.—No special requirements are in force

Russia.—Ditto.

United States.—No special regulations exist in those States where most of the flax spinning is carried on.

(2) *Whether any statistics are available, showing the state of health amongst workers engaged* (a) *in wet spinning,* (b) *in humid weaving,* (c) *in dusty processes, and* (d) *in other dry processes, as compared with the total population of the district?*

Austria.—No information is available.

Belgium.—No information subsequent to 1902 is available

France.—No statistics exist indicating the state of health of the workers in different processes. The workers engaged in spinning and weaving are said to be inferior in health to those in other branches of the textile industry. This is due to two principal causes; one concerned with the actual hygienic conditions, the other purely local.

The former consists in the fact that in both the wet and the dry processes, the working conditions have up to recently at any rate been less favourable from a hygienic point of view. The latter arises from the workers in flax spinning rooms being recruited generally from the less resistant part of the population, the majority of the workers preferring employment in cotton spinning.

The population of Lille in 1911 was 217,807; the number of deaths was 4,478, corresponding to a death rate of 20·5 per 1,000. This number includes 17 male flax spinners, 16 hacklers, 23 weavers, and 29 female spinners, but the figures have no significance, since the proportion of deaths to the number of persons employed in each process is not established.

The weaving of fine linen is carried on in the Cambrai district only, and there are no statistics in regard to it, except by analogy with the spinning or worsted by the process known in England as the French process, which is carried on at a similar temperature and relative humidity. In this process the number of conscripts refused or adjourned is about 30 per cent. as against 12 or 13 per cent. in other professions.

Germany.—No information is available.

Russia.—Ditto.

United States.—There is no official information, but two large firms of flax spinners state that the health of their wet spinners has been excellent and no worse than that of the average mill hand.

(3) *Whether any records exist of body temperatures and other physiological data (rate of respiration, pulse, &c.) of operatives, taken during actual work, such as to assist the Committee to form an opinion as to the particular temperature (wet or dry bulb) at which* (a) *discomfort, and* (b) *injury to health begins?*

Austria.—No information is available.

Belgium.—So far as is known, no medical investigation has been made with the object of determining the critical temperature (dry and wet bulb) beyond which discomfort and ill-health undoubtedly begin. The results of a laboratory research on this subject, undertaken with the approval of the Minister of Labour, has been recently presented to the Belgian Royal Academy of Medicine.

France.—No experimental investigation has yet been undertaken in wet spinning rooms on the rise of body temperature, rate of respiration, pulse rate or arterial blood pressure. For determining the temperature at which workers experience discomfort, the only source of information is the complaints which are brought to light. These complaints are made invariably when the dry bulb temperature reaches 30° C. (86° F.), but cease as soon as there is a movement of air even without diminution of temperature. It has been noticed that injury to health exists when the wet bulb temperature remains regularly above 25° C. (77° F.). A higher temperature reached only occasionally appears not to have the same deleterious effects, and the same applies if the air is kept in movement.

Germany.—No information is available.

Russia.—Ditto.

United States.—Ditto.

(4) *What relative humidity is considered necessary for the efficient weaving of* (a) *fine linen, and* (b) *coarse linen?*

Austria.—Opinions differ so widely that it is impossible to give specific figures.

Belgium.—The Belgian manufacturers are not agreed as to the relative humidity necessary for efficient weaving. The majority simply judge empirically according to the class of goods being made at the moment.

France.—For the weaving of fine fabrics a relative humidity of 85 per cent. is considered indispensable, but this proportion is often exceeded. Experience shows in fact that the higher the relative humidity the less resistance offered by the yarn to traction.

In weaving with coarse yarns, no artificial humidity is used, and for intermediate yarns, either the warp is kept damp with a cloth or the floor is watered.

Germany.—No information is available.

Russia.—Ditto.

United States.—Ditto.

(5) *Whether a certain limit of temperature and of relative humidity is considered necessary for efficient spinning by the wet process?*

Germany.—Opinions differ so widely that it is impossible to lay down general principles.

Belgium.—The majority of flax spinners appear to agree that the high proportion of water vapour in the air of wet spinning rooms as well as the high temperature, are not necessary from the manufacturing point of view, but constitute an inconvenience which is very difficult to remedy.

France.—A temperature of not less than 24° C. (75° F.), with a relative humidity of 80 per cent., appears to give the best conditions for wet spinning. For fine spinning the inspectors have noticed that the temperature is nearly always 27° C. (80·6° F.), with a relative humidity of 75 to 80 per cent. On the other hand, the coarse yarns require hotter water in the troughs, and the temperature of the room is greatly affected thereby. In short, except in fine spinning rooms, the usual temperature is 30° C. (86° F.).

Germany.—No information is available.

Russia.—Ditto.

United States.—There is no official information, but according to a private firm, the best spinning conditions are given by a temperature of 75° F., and a relative humidity of 75 to 80 per cent.

(6) *Whether objection is taken to the use of "splashboards" on wet-spinning frames, and, if so, for what reason?*

Austria.—No objection is raised to the use of splashguards either by the employers or by the operatives.

Belgium.—Splashguards are nearly universal. Exceptions occur in two circumstances only:—(*a*) in a room where old-fashioned spinning frames with inclined spindles are still in use, and on which, for this reason splashguards are impracticable, and (*b*) in rooms where the space between the frames is insufficient to admit of their application.

France.—Splashguards are not in use in spinning rooms in the North of France. All attempts to introduce them have failed. The inspectors have reason to believe that one of the reasons for this was that in France the spinners are more willing to work with bare breasts than in England, and accordingly have less objection to being wetted by the drops of water thrown off from the spindles.

Germany.—No information is available.

Russia.—Ditto.

United States.—No official information. One private firm states that there is no objection to the use of splashguards on wet spinning frames, and another that the operatives do not as a rule object to splashguards, but some spinners consider them in the way when doffing or piecing-up is done.

(7) *Notes of any methods of humidifying, and especially of cooling humid rooms, which are considered efficient.*

Austria.—The methods of humidifying are similar to those in ordinary use, and no special means of cooling exist.

Belgium.—No special means of cooling is known, but on the other hand, in some rooms hot air is introduced during the cold season with a view to reducing the relative humidity in wet spinning.

France.—The inspectors have required that in all or nearly all wet spinning rooms the air shall be continually and abundantly renewed by the introduction of dry air (warmed in winter) properly distributed so as to affect the hygrometric state of the air uniformly. This system of ventilation has greatly improved the hygienic conditions in spinning rooms and has no injurious effect on the manufacture.

Germany.—No information is available.

Russia.—Ditto.

United States.—Ditto.

APPENDIX V.

Petitions, &c. received by the Committee.

I. Petition from the Tenters and Weavers of the Portadown Weaving Company, Limited, received 21st September 1912.

"We, the undersigned, weavers and tenters of the Portadown Weaving Company, wish to inform the Committee on Humidity appointed by the Home Secretary and now sitting in Belfast—

"Firstly, That while we appreciate any effort to better our working conditions we strongly oppose a reduction on the present allowance of artificial humidity, as we know from long experience that the weaving of fine cambrics in which we are engaged requires more humidity than weaving of cotton, and we urge you to fully consider this question.

"Secondly, Further to ask the Committee to recommend to the Home Secretary an increase on the present allowance of artificial humidity inside in frosty and windy weather, and that no one knows better than the weavers themselves, and that we would require a point and a half more than we are getting,

"Thirdly, That weavers could not earn a living if you reduce the present condition of temperature; that a fairly high temperature, not less than 70 degrees, is essential to the best weaving conditions of fine cambrics."

Please do not sign unless you agree with this.

Signed on behalf of the Committee,
Wm. John Rusk, Secretary.
W. Ridpath, Chairman.

(154 signatures follow.)

II. Petition received from the Weavers and Tenters of Messrs. Hamilton Robb, Ltd., Portadown.

"We, the employees of Messrs. Hamilton Robb, Ltd., having been informed that an inquiry is to be held on Wednesday next, dealing with the amount of moisture used in weaving sheds, we regret that by interfering in any way with the present allowance of moisture it would be entirely against our interests as fine cambric workers, and also the means of reducing our weekly earnings. We, therefore, in our own interests, protest against any proposed alteration."

(227 signatures follow.)

III. Resolution passed by the Weavers and Tenters at Messrs. John S. Brown & Sons, Ltd., St. Ellen Works, Shaw's Bridge, Belfast, on 18th September 1912.

At a meeting held at Messrs. John S. Brown & Sons, Ltd., St. Ellen Works, Shaw's Bridge, Belfast, on the 18th September, the following resolution was unanimously passed by the weavers and tenters, proposed by Carlile Dodds (weaver) and seconded by Angus Martin (weaver):—

"That any reduction in the allowance of artificial humidity would add very much to the difficulty in weaving heavy linens and yet have no better results on the health of the weavers. We also consider that a temperature of not less than 70 degrees is essential with a difference of two degrees between the wet and dry bulbs."

IV. Resolution passed by the Weavers and Tenters employed by Messrs. John S. Brown & Sons, Ltd., Lower Lodge Factory, Belfast, on the 20th September 1912.

The weavers and tenters employed in Messrs. John S. Brown & Sons, Ltd., Lower Lodge Factory, Havana Street, Belfast, on the 20th instant, held a meeting at which the following resolution was proposed by Thomas Davison (weaver) and seconded by Aaron Paul (weaver) and passed unanimously:—

"We would prefer that no reduction be made either in temperature or humidity, as from experience tried by reducing both temperature and humidity, we found that it increased our work greatly, as well as producing an inferior article. We consider the temperature at 70–72 degrees should be maintained, from both working and health points of view."

V. Resolution passed by the Weavers and Tenters employed by Messrs. Spence, Bryson & Co., Ltd., Clonavon Factory, Portadown, on the 18th September 1912.

"It is resolved by us, the weavers and tenters of Clonavon Factory, Portadown, to inform the Committee on Humidity appointed by the Home Secretary and now sitting:—

(1) "That while we appreciate any effort to better our working conditions we strongly oppose a reduction on the present allowance of artificial humidity, as we know from experience that such a step would increase our difficulties.

(2) "That a fairly high temperature—not less than 70 degrees—is essential to the best weaving conditions of fine cambrics.

(3) "That as the weaving of fine cambrics, in which we are engaged, requires more humidity than the weaving of coarser fabrics, we claim special consideration for our branch of the industry.

(4) "Further, we ask the Committee to recommend to the Home Secretary an increase on the present allowance of artificial humidity inside the factory when certain unfavourable atmospheric conditions prevail outside."

Proposed by Robert Sloan, seconded by Wm. Carvell, and passed unanimously.

VI. RESOLUTIONS PASSED BY A MEETING OF WEAVERS AT THE LURGAN PHILHARMONIC HALL, ON 26TH SEPTEMBER 1912.

(1) "Resolved that this meeting of the power loom weavers of Lurgan recommends the Home Office to take steps to limit unnecessary and excessive dampness in weaving sheds for the manufacture of linen and cambric fabrics, and reduce the high temperatures prevailing in Lurgan factories during the summer months."
Proposed by Hugh J. Mallon, seconded by Henry Maxwell, and passed unanimously.

(2) "That the temperature of weaving factories be not permitted to fall below 60 degrees of heat during the winter."
Proposed by John Bailey, seconded by Henry Maxwell, and passed unanimously.

VII. PETITION AND LETTER FROM TWELVE LINEN CAMBRIC MANUFACTURERS, DATED 15TH JANUARY 1914.

To Sir Hamilton Freer-Smith and the Members of the Home Office Committee on Humidity in Flax Mills and Linen Factories.

GENTLEMEN,

re Humidity in Weaving Factories.

In view of the fact that it has in the past been found practically impossible to adhere strictly to present regulations, and at the same time to provide the most suitable conditions for carrying on our industry, or satisfy the reasonable requirements of our weavers, we would greatly desire to have the regulations so adjusted that they can be carried out without any unnecessary hardship or cause for friction.

We, the undersigned, Linen Cambric Manufacturers of Portadown, Lurgan, and elsewhere, beg of you to recommend to the Home Office to grant an increase on the present allowance of humidity at and under 70 degrees wet bulb temperatures.

We would confidently ask your sympathetic consideration of this, to us, important matter, believing that your research during the past 1½ years cannot have failed to convince you of the necessity for the change.

We are, Sirs,
Yours faithfully,
(Signed)

Spence, Bryson & Co., Ltd., T. H. Spence.
Parkside Weaving Co., John Acheson.
Blackers Mill, Ltd., Wm. L. Calvert.
Portadown Weaving Co., Ltd., T. Jackson Greaves
Hamilton Robb, Ltd., H. Robb
Lurgan Weaving Co., Ltd., H. G. MacGeagh
W. F. B. Baird & Co., Ltd., W. F. B. Baird.
James Malcolm, Ltd., H. C. Malcolm.
Johnstone, Allen & Co.,
W. J. Allen,
Murphy and Stevenson, Ltd., Arthur W. Stevenson.
The Ravarnette Weaving Co., Ltd., E. A. Sinton.

DEAR SIR,

Home Office, 28th January 1914.

Committee on Humidity in Flax Mills, &c.

In reference to your letter of the 15th instant, enclosing a memorial from certain manufacturers, *re* Humidity in Weaving Factories, I have to inform you that the latter was duly considered by my Committee at a recent meeting.

In reply, I am instructed to say that my Committee would be obliged if the signatories to the memorial would kindly state for their information the precise grounds on which "it has in the past been found practically impossible to adhere strictly to the present regulation."

I should be obliged by a reply as soon as possible, in order that this further information may be submitted to my Committee at their next meeting.

Yours faithfully,
D. R. WILSON,
Secretary.

The Secretary,
Power Loom Manufacturers' Association,
7, Donegall Square, Belfast.

DEAR SIR,

"6th February 1914.

In reply to your letter of the 28th January, asking for the grounds on which 'it has in the past been found practically impossible to adhere strictly to present regulations, and at the same time to provide the most suitable conditions for carrying on our industry, or satisfy the reasonable demands of our weavers.'

The explanation of the above is, that in our experience there are times when the wet and dry bulbs are within two degrees of one another, and yet the weaving conditions are such as to require more humidity, which the weavers demand, and in our opinion with good reason.

Yours truly,
(The same signatories.)

D. R. Wilson, Esq., Secretary,
Committee on Humidity in Flax Mills,
Home Office.

APPENDIX VI.

EXPLANATORY MEMORANDUM, CIRCULATED AMONGST THE TRADE ASSOCIATIONS.

ATMOSPHERIC HUMIDITY.

All air contains a certain quantity of water in the form of vapour, but even if the supply of water is unlimited, the amount taken up by the air at ordinary temperatures can never exceed a certain limit, and if more than this amount is present, it can exist only in suspension as liquid water, as in mist or fog.

Saturation.—This limit of "saturation" varies with the temperature of the air thus:—

At	40° F.	1 cubic foot of	air	can contain	up to about	3	grains of	water,	but no more.
"	50° F.	"	"	"	"	4	"	"	"
"	60° F.	"	"	"	"	6	"	"	"
"	70° F.	"	"	"	"	8	"	"	"
"	80° F.	"	"	"	"	11	"	"	"
"	90° F.	"	"	"	"	15	"	"	"
"	100° F.	"	"	"	"	20	"	"	"

Dampness.—Dampness may be described as the teudency of the water-vapour in the air to condense. For example, air at 60° can contain 5·8 grains of water-vapour per cubic foot and no more; air at 59° degrees can contain 5·6 grains per cubic foot and no more. Hence, if air saturated at 60° be cooled to 59°, 0·2 grains per cubic foot of vapour must condense into water, and be deposited on contiguous objects in the form of dew. In other words, the slightest lowering of the temperature is sufficient to cause deposition of moisture, and such air therefore would feel very damp.

On the other hand, air at a temperature of 60° containing 4·1 grains of water per cubic feet could be cooled to 50° before any moisture was deposited; hence such air would feel very dry.

Absolute Humidity.—Absolute humidity is measured by the weight of aqueous vapour in a given volume of air, *e.g.*, number of grains in 1 cubic foot. From what has been said above, it follows that the absolute humidity in itself has no connection with the dampness or dryness of the air, and it is important to notice that air containing a certain quantity of aqueous vapour, *i.e.*, of a definite absolute humidity, will feel damp at one temperature and dry at another, so that for the estimation of the dampness we require to know the temperature as well as the absolute humidity. Thus, consider air of which 1 cubic foot contains 6 grains of aqueous vapour; it has been stated that air at 100° can contain as much as 20 grains per cubic foot, and at 80° 11 grains per cubic foot. Hence air containing 6 grains per cubic foot, or with an absolute humidity of 6 grains, will feel—

very dry at 100°,
dry at 80°,
very damp at 60°.

Indeed, it may be said, that on a fine dry day in summer the absolute humidity of the air is greater than on a cold, wet day in winter.

Dew Point.—The dew point may be defined as the temperature at which the air begins to deposit moisture in the form of liquid water. It corresponds, therefore, with the temperature, at which the air is saturated, and depends exclusively on the absolute humidity. Thus, imagine air at 80° containing 6 grains per cubic foot; on cooling this air, no moisture will be deposited until 60° is reached (*see* above); 60° therefore is the "dew point." Each value for absolute humidity has a corresponding dew point, and the dampness of the air is measured by the difference between this dew point and the actual temperature of the air; the smaller the difference the greater the dampness.

Relative Humidity.—Air, as a general rule, is not "saturated" with moisture, only a fraction of the total possible quantity of aqueous vapour is present. Relative humidity is that fraction expressed as a percentage, or the ratio of the actual absolute humidity of the air to the saturation value at the same temperature, the latter being taken at 100.

Thus, suppose air at 60° to contain 3 grains of water per cubic foot; the maximum quantity of water it could contain at that temperature, if saturated, is 6 grains per cubic foot. The relative humidity therefore is—

$$\frac{3}{6} \times 100 = 50$$

or, in other words, the air is 50 per cent. saturated.

Relative humidity, taking into account as it does, temperature and absolute humidity, is a direct measure of the dampness of the atmosphere.

Hygrometry.—Hygrometry is the estimation of the dampness of the air.

The usual form of hygrometer is the wet and dry bulb thermometers. The dry bulb thermometer registers the actual temperature of the air; the wet bulb registers the same or a lower temperature, on account of the cooling effect of the evaporation

of the water from the bulb. The dryer the surrounding air, the more quickly will the evaporation take place, and the greater will be the difference between the readings of the two thermometers. If the readings of both are identical, it indicates that no evaporation is taking place from the wet bulb, in other words, the surrounding air is saturated, or the relative humidity 100.

The values for relative humidity are obtained from the readings of the hygrometer by means of special tables. It is important to notice that the wet bulb temperature is not *by itself* a measure of the "dampness" of the air or relative humidity. The important factor in this case is the *difference* between the dry and wet bulb temperatures.

Further, the wet bulb temperature is not as a rule identical with the "dew point," but is intermediate between the dew point and the dry bulb temperature. Only when the readings of the two thermometers are identical, is the dew point the same also.

Physiological Effects of Heat and Moisture.

According to modern physiologists, the important factor in determining degree of discomfort caused by working in a warm, moist atmosphere is neither the dry bulb temperature nor the relative or absolute humidity, but the *wet bulb temperature*. The amount of clothing worn and the degree of exertion exercised on the work are also, of course, of influence. Thus, a man wearing light clothing and doing light work can stand without discomfort a higher wet bulb temperature than a man heavily clad and doing hard work. The symptoms of discomfort are a rise in the temperature of the body (the normal temperature being 98·4° F.) and a general feeling of lassitude and exhaustion.

On this point the following extracts from Appendix III. of the Minutes of Evidence to the First Report of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds (Summary of Evidence by J. S. Haldane, M.D., F.R.S.) may be quoted :—

With a wet bulb temperature exceeding 88° to 90° in fairly still air the body temperature begins to rise, even in the case of persons stripped to the waist and doing no work; and when once started this rise continues until symptoms of heat-stroke arise, unless the person leaves the warm air. In the case of persons doing muscular work, the rise of body temperature is much more rapid and begins at a much lower wet bulb temperature. It will, for instance, begin (in persons stripped to the waist) at a wet bulb temperature of about 80° in still air with moderately hard muscular work, so that hard and continuous work is impracticable at wet bulb temperatures of over 80° in still air. There is no doubt that when ordinary clothes are worn, serious rise of body temperature occurs at a still lower wet bulb temperature. Soldiers marching in uniform are, for instance, liable to heat-stroke at wet bulb temperatures of under 70°.

The persons employed in a cotton cloth factory wear ordinary clothing, and go to and from their meals in this clothing. It is evidently desirable that they should not get wet from perspiration during their work, and in this respect they are in a different position from miners, who can strip during their work, and rest if they get too hot. With a view to my evidence before this Committee, I have recently made some experiments on the effects of moderate heat and moisture on persons wearing their ordinary indoor clothing. I found that in fairly still air and with a wet bulb temperature exceeding about 70°, and with muscular exertion, comparable to that needed in managing looms, the skin and clothes became damp and uncomfortable from perspiration when ordinary indoor clothing was worn. There was little or no discomfort if the wet bulb was below 70°. The effect seemed to be the same whether the temperature by the dry bulb thermometer rose or fell, provided the wet bulb temperature was the same, whereas any rise in the wet bulb temperature above 70° very rapidly increased the effect. With lighter clothing, such as would be worn indoors in summer, a wet bulb temperature of 3 or 4 degrees higher was needed to produce the same effect; and for this reason, and in view of the difficulty of controlling rise of temperature in weaving sheds in summer, I think that the higher wet bulb temperature should be allowable in summer, although a wet bulb temperature below 70° would at all times be preferable.

Legal Limits of Humidity in Various Industries.

Under the Factory Act of 1901 the amount of humidity allowed in textile factories is limited by two schedules.

The first of these applies to cotton weaving and certain other industries. Under it the extent of permissible humidity is reduced as the temperature rises, or, in other words, a greater "dampness" is permitted at low temperatures than at high. Up to 70° dry bulb temperature the difference between the dry and wet bulb readings must be not less than two degrees (corresponding to a relative humidity of about 88 per cent.); above 70°, the difference is gradually increased as follows :—

Temperature.			Maximum Relative Humidity allowed.
Dry Bulb.	Wet Bulb.	*Difference.*	
71	68·5	2·5	88
72	69	3	85·5
73	70	3	84
74	70·5	3·5	84
75	71·5	3·5	81·5

The other schedule of humidity applies to flax spinning, linen weaving, and worsted spinning by the French or "dry" process, and allows a uniform difference of not less than two degrees between the dry and wet bulb readings, whatever the actual temperature. It is, therefore, identical with the other schedule up to 70° dry bulb, but allows more "dampness" at temperatures above 70°.

Recent Legislation.—Under the Act of 1901, no limit was placed on the *temperatures* allowed in humid textile factories, and the Cotton Cloth Factories Schedule of humidity is extended to 100° dry bulb; 91° wet bulb, corresponding to a relative humidity of 64 per cent.

About seven years ago, very strong opposition to "steaming" was shown by the operatives in the Lancashire weaving sheds, which culminated in a ballot being taken of the weavers' opinions in November 1906 with the following results:—

For the abolition of "steaming" - - - -	68,154
Against - - - - - - -	3,094
Neutral - - - - - - -	1,221
Total voting - - - - -	72,469

In consequence of this, a Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds was appointed by the Secretary of State in November 1907, with the following terms of reference:—

To inquire and report,—

(1) What temperature and humidity are necessary in each case for the manufacture of different classes of cotton fabrics;

(2) At what degrees of heat and humidity combined definite bodily discomfort arises, under the conditions of the work carried on by the operatives and what, if any, danger to health is involved by continuous work at those degrees;

(3) What means of cooling humid sheds (where necessary) exist, whether combined with the means of humidifying or otherwise, which are both efficient and practicable, having regard to the conditions required for the manufacture of the several classes of goods;

(4) What special arrangements, if any, are necessary in order to admit of the proper ventilation of dry weaving sheds without prejudice to the process of manufacture.

On behalf of this Committee an investigation into the physiological conditions of weavers working in warm, humid atmospheres was undertaken by Dr. M. S. Pembrey, M.D., Lecturer on Physiology at Guy's Hospital, and member of the Army Medical Advisory Board of the War Office, and Dr. E. L. Collis, M.B., H.M. Medical Inspector of Factories, whose report will be found in Appendix III. of the Second Report of the Committee, and whose conclusions are summarised in the Report itself, as follows:—

In their opinion, the amount of exercise is insufficient to produce an unusual rise of body temperature: the physiological effect upon the worker at any given wet bulb temperature will depend partly upon the duration and amount of work done and partly on the power of resistance of the individual; and the influence of a warm, moist atmospere is to diminish the difference between the internal temperature of the body and that of the peripheral parts, and to establish a more uniform temperature of the body as a whole, a condition which, in their opinion, would go to explain the discomfort and low state of health of which the weavers complain.

The conclusion is drawn that prolonged exposure to a hot, moist atmosphere would appear to be more injurious than exposure to an even higher wet bulb temperature for a short time, and that it would be advantageous to fix the limit of wet bulb temperature as low as possible.

Recently, Regulations, based on the recommendations of that Committee, have been made, which enact (amongst other things) that, while the differences between the dry and wet bulb temperatures remain the same as in the schedule previously in force, all steaming or other artificial humidification shall cease when the wet bulb temperature reaches 75°.

The object of this regulation is to prevent the wet bulb temperature from rising much above 75°, but it is important to notice that in a hot factory the dry bulb temperature will continue to rise after the cessation of humidification, and the difference between the dry and wet bulb readings will increase, or, in other words, the relative humidity or "dampness" will diminish.

The remedy, as pointed out on p. 13 of the First Report of the Committee, is to adopt means for cooling the factory, so that the dry bulb temperature is prevented from rising, and the difference between the dry and wet bulb temperatures remains fairly small.

OBJECT OF PRESENT COMMITTEE.

The present Departmental Committee on Humidity in Flax Mills and Linen Factories was appointed by the Secretary of State on the 17th July 1912 with the following terms of reference :—

> "To inquire and report what amendment (if any) of the Regulations for the spinning and weaving of flax or tow, and the process incidental thereto, is expedient in view of the Report of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds or on other grounds."

The Committee is constituted as follows :—

*Commander Sir Hamilton Freer Smith, R.N., C.S.I. (formerly Superintending Inspector for Dangerous Trades), Chairman.

*Professor J. E. Petavel, F.R.S. (Professor of Engineering in the University of Manchester).

*Professor J. Lorrain Smith, F.R.S. (Professor of Pathology in the University of Manchester).

Mr. G. Herbert Ewart (of Messrs. William Ewart and Sons, Limited, of Bedford Street, Belfast).

Mr. Henry Cummins (Chairman of the Weavers' and Winders' Trade Union, Lurgan).

The Secretary (to whom all communications should be addressed) is *Mr. D. R. Wilson, Factory Department, Home Office, London, S.W.

It will be seen therefore that the object of the present Committee is not necessarily to extend without change to the flax industry the recommendations of the former Committee on Cotton Weaving, but to consider, after due inquiry whether the health conditions in Ireland are similar to those in Lancashire, how far and with what modifications such recommendations can be applied, having regard to the conditions necessary for the manufacture of flax and linen.

November 1912.

APPENDIX VII.

NOTE ON TERMS DEFINING YARN AND CLOTH IN THE IRISH FLAX AND LINEN TRADES.

Yarn Measurement.—The unit of length is known as the "*cut*" or "*lea*," which is 300 yards. The fineness of the yarn is then defined by the number of leas to the pound Thus, a yarn of 80's *lea* means yarn of such fineness that 80 × 300 or 24,000 yards weigh one pound. The finest yarn spun is about 250's lea, of which 75,000 yards or about 42½ miles weigh one pound.

Cloth Measurement.—The closeness of the weave is defined by the "*sett*" in the warp, and the "*shots*" in the weft.

For warp settings the unit of breadth is 40 inches, and the "*sett*" is defined by the number of reed openings in 40 inches of reed. As each reed opening contains two "*ends*," or individual threads, the total number of ends in 40 inches of reed is the "*sett*" multiplied by two. Thus, a sett of "*nineteen hundreds*" (generally written 19^{00}) indicates a cloth made with a reed in which there are 1900 × 2 or 3,800 ends in 40 inches. The finest plain cloth made on power looms has a sett of 24 hundreds, corresponding to 4,800 ends in 40 inches, or 120 threads to the inch.

For weft measurement the unit of length is 37 inches, and the number of "*shots*" or "*picks*" is defined by the number of individual threads visible under a so-called 37-inch glass. The distance covered by this

* Members, &c. of the former Committee on Cotton Weaving.

measure or glass is $\frac{1}{200}$ths of an inch, so that a cloth with "*nineteen shots*" of weft is one in which there are 19 × 200 or 3,800 threads in a length of 37 inches, or 102·7 threads to the inch.

A cloth is usually sufficiently defined by the sett, number of shots and name, thus 20/19 *cambric*, 18/16 *fine shirting*, since the leas of the yarn used are generally the same for the same standard manufacture.

Where the warp and the weft are defined by equal numbers the cloth is known as "*square*."

APPENDIX VIII.

Memorandum on the Body Temperature, by Professor J. Lorrain Smith, M.D., F.R.S.

The temperature of the human body is regulated by means of the nervous system, and in virtue of this it is maintained in ordinary healthy conditions at a point which is determined by the body itself and not by the variations in the temperature of its surroundings.

This point we may describe as a constant point, though variations through a certain range occur normally: the average temperature is 98·6° Fahrenheit, the maximum is 99·5° Fahrenheit, and the minimum is 96·8° Fahrenheit. Variations beyond these limits are outside the normal range and indicate the existence of some abnormal conditions.

One of the most obvious external conditions affecting the body temperature is that of surrounding air, and in the consideration of this the moisture as well as the temperature of the air must be taken into account, because the body regulates its temperature by varying (*a*) the quantity of heat given off, and (*b*) the quantity of moisture evaporated from the skin surface.

In a hot dry air the amount of evaporation increases: the sweat is poured out from the glands of the skin and evaporates from the surface.

From this it follows that a man may be exposed to a temperature hotter than that of his body, but while sweating and evaporation into the dry air continues his body temperature does not rise.

On the other hand, if the air be moist and hot at the same time the regulation of the body temperature becomes correspondingly difficult, because there is diminished loss of heat and less evaporation, and when a certain point is reached the temperature of the body can no longer be kept within the normal range.

The point at which temperature regulation in these conditions becomes impossible is indicated by the reading of the wet bulb thermometer.

Haldane found by experiment that in still air with the wet bulb thermometer at 88° the body temperature did not show any abnormal increase, but if this were exceeded by even 1 degree a very marked rise in the body temperature took place (1·0°—1·4° per hour).

In these experiments the subjects were stripped to the waist, or were clad in light flannel, and were doing no work.

When heavier clothing was worn and when work was done at the same time the limit of the wet bulb temperature which could be borne without abnormal rise in body temperature was much lower. Thus a subject clothed in the way described, but doing leisurely climbing (13 feet per minute) showed abnormal rise of body temperature when the wet bulb was at 78° Fahrenheit or 10 degrees lower than that which affected him when he remained at rest.

On the other hand it was found that the movement of the air was of importance: a current of air aids the evaporation by carrying away the moisture given off by the skin, and in this way makes it possible to tolerate a temperature which in still air would produce an abnormal rise.

APPENDIX IX.

Report on Body Temperatures, &c., of Spinners and Weavers, by T. M. Legge, M.D., H.M. Medical Inspector of Factories.

Factory Department,
Home Office,
London, S.W.

Sir,

A letter received from the Secretary of your Committee, dated 26th July 1912, stated that the questions you had to consider were mainly: "(1) Whether discomfort and ill-health exist amongst the "operatives exposed to the high wet-bulb temperatures prevailing in many wet spinning rooms and "humid weaving sheds, and (2) What means can be devised for improving the conditions." Having previously in 1909 at your request, as Chairman of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds, supervised the taking of a number of mouth temperatures of weavers in humid cotton sheds, to see whether rise in them coincided with rise in the height of the wet-bulb thermometer, I deemed similar procedure in humid processes in flax and linen mills would most readily answer the first of your questions.

The report and tables giving the results of the inquiry in 1909 appear as an Appendix to your Report on Humidity and Ventilation in Cotton Weaving Sheds.* The conclusion I came to I stated as follows:—

> "The general opinion I have formed from the detailed study of the observations is that a rise of mouth temperature makes itself distinctly felt when the temperature of the wet bulb exceeds 75° F.; in other words, that weavers are likely to be, when this is the case, working under adverse physiological conditions."

In carrying out your wishes in 1912 in humid processes in flax and linen factories the same procedure was adopted as in the earlier inquiry. The instructions given to the observers are printed as an Appendix, and I need not therefore detail them here. At the commencement I interviewed each one of the observers, and, subsequently, after the work was completed, saw them again and visited with them the sheds and rooms in which the workers whose temperatures had been taken were employed.

* Cd. 5566.

Eventually, the results of observations, totalling 1,509, were received from Dr. E. B. Purdon, Belfast (in 1 spinning, 1 weaving, and 1 spinning and weaving mill); Dr. W. Massy Burnside, Belfast (in 1 weaving mill, including observations in a yarn dressing room), Dr. G. L. St. George, Lisburn (3 weaving sheds), Dr R. Reid, Whiteabbey, near Belfast (1 spinning room); and Dr G. Dougan, Portadown (1 weaving shed). The total number of observations was nearly twice as large as that in Lancashire, and as the summer was hot, when compared with 1909, the results generally of this inquiry seem to me on the whole more conclusive than those of the previous one.

Table I. shows the number of persons of either sex under observation, and the number of those in whom double observations were made. The importance of the double observation is that comparison is thereby possible of the mouth temperature before exposure to the condition of the atmosphere, the effect of which is to be tested, and again, some hours later, when the effect (if any) will have been shown. This is brought out in Table II.

TABLE I.

District.	Persons examined.		Observations.		Double Observations on same Person on same Day.	
	M.	F.	M.	F.	M.	F.
Belfast	5	51	148	860	70	418
Lisburn	8	10	118	178	59	89
Portadown	6	5	45	50	15	18
Whiteabbey	2	18	8	102	0	0
All districts	21	84	319	1,190	144	525

TABLE II.

District.	Early Observations.						Late Observations.					
	Male.		Female.		Control		Male.		Female.		Control	
	No.	Average.	No.	Average.	No.	Average.	No	Average.	No.	Average.	No.	Average.
Belfast	68	98·1	394	98·4	28	98·3	70	98·8	397	99·3	49	98·6
Lisburn	34	98·6	89	98·7	25	98·4	34	98·6	89	98·7	25	98 4
Portadown	18	98·9	20	99·0	—	—	27	99·0	30	99·3	—	—
Whiteabbey	1	98·4	18	99·1	—	—	7	99·2	84	99·6	—	—
All districts	121	98·4	521	98·5	53	98·4	138	98·8	600	99·2	74	98·5

The figures make it sufficiently clear first, that in both males and females there is a tendency for the mouth temperature at the later observation to be higher than at the earlier one; and, secondly, the temperature of the women at both sets of observations is higher than that of the men. The fact that the spinners and weavers show decidedly higher temperatures than the controls shows that the first point is dependent upon employment, and is not due merely to the slight normal rise late in the afternoon marking the maximum diurnal variation in the body. The rather low temperatures among women in Belfast at the early observations as compared with the other towns is accounted for by at least 400 observations having been made between 6 and 7.30 a.m., when the mouth temperature is near the minimum of the daily variation.

Table III. shows the average mouth temperature, rate of respiration and pulse, of males and females at five groups of wet-bulb temperatures between 61° F. and 85° F.

TABLE III.

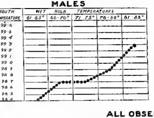
Wet-bulb Temperatures.	Early Observations. Average.						Late Observations. Average.					
	Mouth Temperature.		Pulse.		Respiration.		Mouth Temperature.		Pulse.		Respiration.	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
61°–65°	98·8	98·5	82·9	90·5	19·0	19·8	98·4	98·6	88·0	85·3	22·0	23·3
66°–70°	98·2	98·4	85·4	85·3	18·9	18·6	98·7	99·1	80·3	84·4	19·3	19·2
71°–75°	98·3	98·6	85·0	85·3	19·0	19·3	98·7	99·1	78·6	84·8	18·8	20·2
76°–80°	99·0	98·9	77·3	78·0	16·9	19·3	98·9	99·3	82·7	80·9	20·0	20·8
81°–85°	—	—	—	—	—	—	99·3	99·7	74·3	90·4	17·0	22·4
All temperatures	98·4	98·5	80·4	85·9	19·0	19·1	98·8	99·2	80·2	87·3	19·2	20·8

Wet-bulb Temperatures	Control Observations. Average. Mouth Temperature. M	F.	Pulse. M.	F.	Respiration. M.	F.	All Observations. Average. Mouth Temperature. M.	F.	Pulse. M.	F.	Respiration. M.	F.
61°–65°	98·5	98·5	73·0	81·4	16·6	21·2	98·6	98·5	76·0	87·1	17·8	20·4
66°–78°	—	—	—	—	—	—	98·4	98·6	83·4	85·1	19·1	19·1
71°–75°	—	—	—	—	—	—	98·5	98·9	81·3	85·0	18·9	19·8
76°–80°	—	—	—	—	—	—	98·9	99·2	82·0	87·7	19·5	20·6
81°–85°	—	—	—	—	—	—	99·3	99·7	74·3	90·4	17·0	22·4
All temperatures	98·5	98·5	73·0	81·4	16·6	21·2	98·6	98·9	80·4	86·3	18·6	20·0

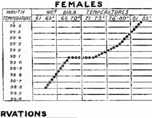
This table is instructive as it shows, invariably for both sexes (although more markedly in women at the late observations than in the men), definite rise at wet-bulb temperatures over 75° F. Corresponding rise in the average pulse and respiration rate is not well brought out, but is traceable in the pulse rate of the women. This table is more convincing than the corresponding Table III. in my previous report on temperatures in cotton weaving sheds. The curves here reproduced illustrate the point diagrammatically.

LATE OBSERVATIONS

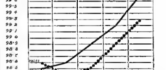
MALES



FEMALES



ALL OBSERVATIONS



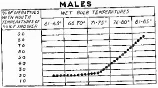
The influence of the height of the wet-bulb thermometer in slightly raising the mouth temperature is similarly illustrated in Table IV. and in the curve showing the number and percentage of male and female temperatures at 99° F. and over, and under 99° F. at the five groups of wet-bulb temperatures.

TABLE IV.

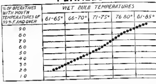
Mouth Temperature of Operatives at different Wet-bulb Temperatures.

Wet-bulb Temperatures.	Males. Temperatures of 99° F. and over. Number.	Per Cent.	Males. Temperatures under 99° F. Number.	Per Cent.	Females. Temperatures of 99° F. and over. Number.	Per Cent.	Females. Temperatures under 99° F. Number.	Per Cent.
61°–65°	15	17·6	70	82·4	34	17·6	159	82·4
66°–70°	17	17·9	78	82·1	101	35·4	184	64·6
71°–75°	19	21·4	70	78·6	171	54·0	145	46·0
76°–80°	24	49·0	25	51·0	260	80·2	64	19·8
81°–85°	5	83·4	1	6·6	53	98·2	1	1·8
All temperatures	80	24·6	244	75·4	619	52·7	553	47·3

MALES



FEMALES



Of the women only one observation (1 8 per cent.), out of 54 taken at wet-bulb temperatures of 81° F.–85° F., had a mouth temperature under 99° F., whereas 488 (61·4 per cent.) out of 794 observations were under 99° F. when the wet bulb recorded less than 75° F. The table shows that as the wet-bulb temperature rises so does the mouth temperature, and this is very marked when the wet bulb rises above 75° F. The conclusion arrived at in the corresponding Table IV. in my previous report is thus borne out by the present inquiry.

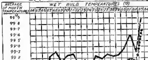
Table V., and the accompanying curve illustrating it, show the closeness of the relationship between the height of the wet-bulb and the mouth temperature.

TABLE V.

Average of all Mouth Temperatures at late Observations at different Wet-bulb Temperatures.

Wet-bulb Temperature.	Mouth Temperatures. Male. No.	Male. Average.	Female. No	Female. Average.	Wet-bulb Temperature	Mouth Temperatures. Male. No.	Male. Average	Female. No.	Female. Average.
°					°				
64	—	—	—	—	75	11	98·84	35	99·22
65	2	98 40	3	98 60	76	8	98·78	51	99 19
66	2	98·40	5	98·52	77	11	99·10	91	99·25
67	—	—	6	99 23	78	13	98·66	46	99·22
68	15	98·79	14	99 33	79	1	98·60	46	99·24
69	7	98 86	24	99·14	80	11	99·07	56	99·38
70	15	98 68	25	99·26	81	2	99 20	30	99·61
71	12	98·72	21	99 28	82	3	99·13	2	99·30
72	2	98·40	37	99·10	83	2	99·70	23	99·90
73	14	98·71	45	99·17	84	—	—	—	—
74	8	98 62	37	98·98	85	—	—	—	—

LATE OBSERVATIONS



In all but 24 observations (all males) the dry-bulb temperature recorded only a few degrees more than the wet, and very much the same result as is here shown for the wet bulb would have been obtained had the dry-bulb temperature been taken as the criterion. But that it would not be a true index is brought out especially where differences between the temperatures of the dry and wet bulb are considerable as in the hot atmosphere of yarn dressing rooms. The following observations by Dr. Burnside in such a room demonstrate that even when the dry-bulb records 100° F. and over, the rise in the mouth temperature is not higher than it would be had the temperature of the dry bulb approximated closely to that of the wet.

Date.	Time (Hour and Minute).	Temperature (° Fahr.). Mouth.	Dry Bulb.	Wet Bulb.	Shade Outside.	Pulse.	Respirations.
			°	°	°		
W. J., 64 - 2.9.13	9.35 a.m.	98·4	90	70	61	90	14
2.9.13	5.45 p.m.	99·0	111	85	58	92	19
5.9.13	9.0 a.m.	98·5	92	74	58	102	20
5.9.13	5.15 p.m.	99·6	109	81	62	100	20
15.9.13	6.40 a.m.	97·0	78	70	51	84	18
15.9.13	5.15 p.m.	98·6	102	77	55	96	20
J. B., 44 - 2.9.13	9.40 a.m.	99·0	90	70	61	75	15
2.9.13	5.10 p.m.	99·2	111	85	58	61	16
5.9.13	9.10 a.m.	98·8	92	74	58	80	16
5.9.13	5.10 p.m.	99·3	109	81	62	63	16
15.9.13	7.10 a.m.	98·2	78	70	51	60	12
15.9.13	5.15 p.m.	99·6	102	77	55	60	15
J. McA., 23 - 11.7.13	9.10 a.m.	99·0	100	80	60	94	14
11.7.13	1.0 p.m.	99·3	95	75	61	80	13
25.7.13	9.10 a.m.	98·1	110	90	61·5	89	16
25.7.13	12.40 p.m.	99·4	115	85	65	103	18
5.8.13	7.0 a.m.	98·0	90	78	60	72	17
5.8.13	1.0 p.m.	99·3	105	85	64	94	17
A. McK., 45 - 11.7.13	9.35 a.m.	99·4	100	80	60	96	21
11.7.13	1.0 p.m.	99·2	95	75	61	88	18
25.7.13	9.15 a.m.	98·6	110	90	61·5	86	16
25.7.13	12.45 p.m.	99·2	115	85	65	92	14
5.8.13	6.45 a.m.	98·6	90	78	60	79	11
5.8.13	1.0 p.m.	98·8	105	85	64	76	11

Table VI. gives particulars of all observations where mouth temperatures of 100° F. and over were recorded. Of the 59 mouth temperatures of 100° F. or over, 44 (74·6 per cent.) were at wet-bulb temperatures of 75° F. or over. The table shows that mouth temperatures of over 100° F. are not associated necessarily with high relative humidity. The outstanding feature again of this table is the greater susceptibility of women, as compared with men, to respond to the infinence of the wet-bulb temperature.

The average pulse and respiration rate of the persons employed with mouth temperatures of 100° F. or over, were 95·1 and 22·2 respectively, as compared with 84·3 and 19·6—the average of all observations. The corresponding figures for the analogous inquiry in cotton weaving sheds in 1909 were 101 and 23. Regarding as normal a pulse rate per minute of 72 and respiration rate of 16, the above figures do suggest that, continned for hours, day after day and year after year, the effect would be likely in the long run somewhat to affect health. In other words, persons in an atmosphere, when the wet bulb exceeds 75° F., are working under adverse physiological conditions.

At my visit to the spinning rooms and weaving sheds in October, I noted from the hygrometric record kept in pursuance of Reg. 4 of the Flax Regulations, the number of occasions on which in the three months, July to September, the wet bulb had exceeded a temperature of 80° F. In one it had done so on 39 occasions (here only 13·6 per cent. of the observations showed month temperatures less than 99° F.); in two on 23; in a third on 14; and in a fourth on 14. The number of occasions on which wet-bulb temperatures of over 75° F. were recorded was naturally many more. In one small weaving shed, during the three months in qnestion, no wet-bulb temperature as high as 80° F. was recorded, and here 76·2 per cent. of the observations showed mouth temperatures less than 99° F.

TABLE VI.

Mouth Temperatures of 100° F. and over, with corresponding Pulse Rate, Respiration Rate, and Atmospheric Conditions.

Time (p.m.)	Period from Beginning or Resumption of Work.	Mouth Temperature.	Pulse Rate.	Respiration Rate.	Atmospheric Conditions. Temperature. Dry Bulb.	Wet Bulb.	Relative Humidity.
Hr. min.	Hr. min.	°					Per Cent.
5 35	3 50	101·0	114	26	84	80	80
4 40	2 40	100·8	126	22	82	79	85
4 35	2 35	100·4	120	24	81	77	80
4 25	2 25	"	120	23	82	79	85
4 45	2 45	"	128	24	83	80	85
5 55	3 55	100·3	98	25	81	80	95
5 25	3 25	100·2	108	24	78	73	75
5 10	3 10	"	88	22	77	71	71
5 10	3 10	"	80	24	82	77	76
5 5	3 5	"	88	25	76	70	71
3 15	0 30	"	80	16	82	78	80
5 10	3 10	"	88	25	75	68	66
5 10	3 25	100·0	108	24	78	73	75

Time (p.m.).	Period from Beginning or Resumption of Work.	Mouth Temperature	Pulse Rate	Respiration Rate.	Atmospheric Conditions.		
					Temperature.		Relative Humidity.
					Dry Bulb.	Wet Bulb.	
Hr. min	Hr. min.	°					Per Cent.
5 15	3 30	100·0	100	21	83	78	76
5 15	3 30	,,	102	25	84	80	80
4 55	3 10	,,	140	26	81	76	68
5 20	3 20	,,	88	21	79	75	80
5 0	3 0	,,	90	24	80	71	59
5 20	3 20	,,	100	24	79	75	80
4 55	2 55	,,	74	24	75	68	66
5 0	3 0	,,	100	26	77	70	67
4 55	2 55	,,	114	22	82	79	85
4 55	2 55	,,	98	23	81	78	85
4 30	2 30	,,	90	22	80	77	85
4 45	2 45	,,	98	20	80	77	85
5 5	3 5	,,	82	21	81	74	68
5 5	3 5	,,	90	23	79	72	67
12 45	3 45	,,	92	27	80	76	80
5 30	2 45	,,	80	16	77	73	79
3 5	0 20	,,	82	18	79	76	85
2 15	0 15	,,	80	15	73	70	84
2 18	0 18	,,	72	15	78	71	67
2 10	0 10	,,	72	14	72	67	74
2 12	0 12	,,	72	15	72	67	74
4 20	**2 20**	**100·0**	**96**	**22**	**78**	**77**	**94**
6 0	4 0	100·0	104	19	78	77	94
5 50	3 50	,,	107	23	82	80	95
5 45	3 45	,,	107	18	78	77	94
5 10	3 10	,,	96	22	78	77	94
2 0	0 0	,,	114	21	78	77	94
6 0	4 0	,,	105	19	78	77	94
4 20	2 20	,,	84	20	78	77	94
5 0	3 0	,,	90	24	85	81	80
4 15	2 15	,,	94	24	85	83	90
4 15	2 15	,,	94	24	85	83	90
4 30	2 30	,,	96	26	85	83	90
5 8	3 8	,,	98	22	85	81	80
5 10	3 10	,,	92	22	83	80	85
4 10	2 10	,,	94	24	83	81	90
4 15	2 15	,,	96	24	85	83	90
4 25	2 25	,,	98	24	85	83	90
4 30	2 30	,,	98	24	85	83	90
4 35	2 35	,,	98	26	85	83	90
4 50	2 50	,,	98	24	85	83	90
5 30	3 30	,,	98	24	83	80	85
4 35	2 35	,,	96	24	83	81	90
4 35	2 35	,,	98	26	85	83	90
4 35	2 35	,,	98	20	83	81	90
4 40	2 40	,,	98	22	85	81	80

The figures in thick type refer to males; the others to females.

Dr. Reid, in forwarding his results, says, "*All the girls chosen were healthy looking. You will see the* " *highest temperature is* 100°. *The pulse rate seems high, but I attribute this to nervousness and excitement.* " *I found it very difficult to count accurately the respiration rate*"; and Dr. Burnside:—"*The results of* " *my investigations prove fairly conclusively that the temperature of weavers rises as the day wears on. It is in* " *nearly every case higher in the afternoon than in the morning. My usual custom was to examine the workers at* " *9 a.m. on their way in to work after breakfast (8 a.m. to 9 a.m.), and again just before leaving for dinner* " *at 1 p.m. or about 5 p.m. A number of workers had temperatures above normal even at 9 a.m., and generally* " *speaking, they were still higher at the later examination on the same days. On two occasions I went to the* " *mill at 6.30 a.m., and at that time found nearly all the temperatures sub-normal, or at all events not above* " *normal. I also examined some men employed in the dressing-room, and found their temperatures up in the* " *afternoon as compared with the morning. I found some difficulty in getting dressers to submit to examination,* " *as they felt their time was being wasted.*"

This report should be read in conjunction with my previous one dealing with the same subject in cotton humid sheds, as points such as the effect of clothing in influencing heat retention in the body are there alluded to, and bear equally upon the facts elicited in flax and linen mills.

My cordial thanks are due to the several certifying surgeons for the care taken and interest shown in the task set them, and to employers and employed alike for their ready acquiescence and help, and to Mr. D. R. Wilson for the labour involved in collating the figures.

I am, Sir,
Your obedient Servant,
T. M. LEGGE.

Commander Sir Hamilton P. Freer-Smith, R.N., C.S.I.,
Chairman of the Departmental Committee on Humidity
in Flax Mills and Linen Factories.

APPENDIX X.

REPORT ON EXPERIMENTAL WORK IN LINEN-WEAVING FACTORIES AND FLAX-SPINNING MILLS.

By J. E. Petavel, D.Sc., F.R.S., C. H. Lander, M.Sc., A.M.I.C.E., and Margaret White, M.Sc.

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A.—WEAVING.

B.—SPINNING.

INTRODUCTION

The general question of the conditions prevalent in the weaving sheds of the Lancashire district was dealt with at length in the Second Report of the Departmental Committee* on Humidity and Ventilation in Cotton-Weaving Sheds. Appendix V. of the Report included also the results of experimental investigations into various methods of ventilation and cooling, while some recommendations were made with regard to structural design.

Comparison between Conditions in Cotton and Linen Weaving.

Although the manufacturing conditions found in flax spinning and linen weaving in the North of Ireland differ in some important respects, the more fundamental conclusions drawn from the previous work are for the most part of general application.

The essential differences between the usages of the two trades may be briefly enumerated as follows:—

1. In the linen sheds the number of weavers employed is double that of the average cotton shed; for whereas a skilled weaver in the cotton trade may take charge of four looms, the more exacting work of linen weaving restricts the number of looms to which an operative can attend to two, or in some cases even to one.
2. Below 70° F., dry bulb the humidity allowed in linen and cotton-weaving sheds is the same, but above 70° F., the amount of moisture introduced into the linen sheds is much greater

TABLE I.

Comparison of Percentage Humidity allowed in Cotton and Linen Weaving Sheds

Dry Bulb Temperature (degrees Fahr.)	Percentage Humidity In Cotton Shed.	Percentage Humidity In Linen Shed.	Dry Bulb Temperature (degrees Fahr.)	Percentage Humidity In Cotton Shed.	Percentage Humidity In Linen Shed.
(1)	(2)	(3)	(1)	(2)	(3)
50	86	86	80	77·5	90
60	88	88	81	76	90
70	88	88	82	74	90
71	85·5	88	83	74	90
72	84	89	84	72	90
73	84	89	85	72	90
74	81·5	89	86	72	90
75	81·5	89	87	71	90
76	79	89	88	71	90
77	79	89	89	71	90
78	77	89	90	69	90
79	77·5	90			

Note A.—*Up to 70° F. the percentage is the same in both cases.*

Note B.—*No introduction of artificial humidity above 75° F. wet bulb (corresponding to 79° F. dry bulb) is now allowed in a cotton shed, the figures given refer to the amount allowed prior to the Regulations of* 1911.

The high relative humidity judged necessary for the cambric trade renders most methods of cooling less easy of application.

3. The linen looms in general are of heavier build and run at a lower speed than the cotton looms.
4. In linen manufacture heavy sizing is unknown, and dressing is applied for manufacturing purposes only.

The question of cotton spinning did not fall within the purview of the 1910 Committee, but flax spinning is considered in detail in the present report.

Mills and Factories investigated.

During the summer months of 1912 and 1913, a large number of observations were taken and experiments made in Irish weaving sheds and spinning rooms, while the conditions under which similar manufactures are carried out in Scotland and in Belgium were also inquired into.

Self-recording thermometers or hygrometers were installed for the summer in the following mills and factories:—

Weaving Factories.

Name of Firm.	Name and Address of Factory.	Director or Manager
Johnstone, Allen & Co.	Woodville Factory, Lurgan	Mr. Johnstone.
Malcolm, J., Ltd.	Lurgan Weaving Factory, Lugan	Mr. T. Plenderleith.
Parkside Weaving Co.	Portadown	Mr A. McAlister.
Portadown Weaving Co.	Armagh Factory, Portadown	Mr. J. Greeves.
Robb, Hamilton	Edenderry Portadown	Mr. Mullin.
Smithfield Weaving Co., Ltd.	Smithfield Mill, Belfast	Mr. A. T. Herdman and Mr. N. G. Bell.
Ulster Weaving Co., Ltd.	Linfield Factory, Belfast	Mr. J. S. Larmor.

Spinning Mills.

Name of Firm.	Name and Address of Factory.	Director or Manager.
Andrews, J. & Co.	Comber	Mr. J. Andrews.
Cogry Flax Spinning Co., Ltd.	Cogry Mill, Doagh	Mr. Wilson.
Falls Flax Spinning Co., Ltd.	Belfast	Mr. J. Gray.
Greeves, J. and T. M., Ltd.	Belfast	Mr. Eves.
Jaffé Spinning Co., Ltd.	Belfast	Mr. S. Allen.
Martin, H. and Co., Ltd.	Shrigley Mill, Killyleagh	Mr. A. T. Herdman.

* [Cd. 5566.]

In order to correlate the present work with the cotton inquiry, an instrument was also kept in operation, by kind consent of the manager, Mr. J. Bolton, in one of the Lancashire sheds previously investigated, namely, Messrs. Greenwood Brothers, Hollinbank Mill, Blackburn.

The thanks of the Committee are due to the Directors of the above companies for the facilities granted, and to the managers for their co-operation in the work.

Meteorological Conditions.

Although much has been done to perfect the artificial conditioning of the atmosphere in Textile Factories, the climate of the working districts has none the less an important bearing both upon manufacturing facilities and the personal comfort of the operatives.

A study of the mean conditions from the 30 years' averages 1881–1910 (as published by the London Meteorological Office) shows that the North district of Ireland is in summer about one degree cooler than the Lancashire district, and in winter about one degree warmer. The average difference for the year works out at only 0·2°, the mean temperatures being respectively 48·0° F. and 48·2° F. (*See* Table 2.)

TABLES 2a and 2b.

Meteorological Information.

Table 2a.

Mean Conditions from 30 Years' Average, 1881–1910, and for 1913.

Period.	Ireland, N.					England, N.W.				
	Mean Temperature	Hours Sunshine.		Rain.		Mean Temperature.	Hours Sunshine		Rain.	
		Total	Daily Mean.	Total Fall.	No of Days.		Total	Daily Mean	Total Fall	No of Days.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1881–1910	°F			Inches.		°F.			Inches.	
January, February, March	41·0	220	2·4	9·2	61	40·0	220	2·4	8·0	52
April, May, June	50·3	500	5·5	7·6	52	50·7	550	6·0	6·8	44
July, August, September	56·1	380	4·2	10·1	58	57·3	470	5·1	9·4	48
October, November, December.	44·6	190	2·0	11·4	65	44·6	170	1·9	11·1	57
Whole year	48·0	1,280	3·5	38·4	235	48·2	1,410	3·8	35·3	201
1913										
January, February, March	41·7	190	2·1	10·9	64	41·2	200	2·2	10·0	58
April, May, June	49·1	410	4·5	10·6	63	50·5	430	5·3	8·7	52
July, August, September	56·0	410	4·6	6·1	43	57·6	490	5·4	6·2	34
October, November, December.	46·9	190	2·0	11·8	65	47·3	200	2·0	9·6	59
Whole year	48·4	1,200	3·3	39·4	235	49·2	1,320	3·7	34·5	203

Table 2b.

Mean Monthly Temperatures at certain Stations in Ireland.

Period.	Mean Monthly Temperatures.						
	Donaghadee.			Armagh.			Belfast.
	1913.	Normal.	Difference.	1913.	Normal.	Difference.	1913.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
January	41·1	40·4	0·7	40·4	39·0	1·4	40·1
February	42·3	41·0	1·3	41·6	40·0	1·6	42·2
March	41·8	42·2	−0·4	41·9	41·5	0·4	42·4
April	45·0	45·8	−0·8	45·8	45·6	0·2	46·3
May	49·4	50·2	−0·5	50·4	50·4	0·0	50·6
June	53·8	55·4	−1·6	51·8	56·2	−1·4	55·1
July	56·0	57·7	−1·7	56·9	58·4	−1·5	56·9
August	56·9	57·5	−0·6	58·1	57·8	0·3	58·0
September	55·7	54·7	1·0	55·5	53·8	1·7	55·6
October	51·6	48·7	2·9	51·0	47·3	3·7	51·4
November	46·9	44·4	2·5	46·0	42·8	3·2	46·0
December	42·3	41·5	0·8	40·6	39·1	1·5	41·2

Moreover in summer the bright sunshine recorded in North Ireland is considerably less than for the Lancashire district, but at other seasons the differences are not large, and in autumn the North of Ireland is rather sunnier than Lancashire.

At all times of the year the number of rain-days is greater in this part of Ireland than in Lancashire, and the total precipitation (38·4 inches) is 3 inches in excess. The average yearly humidity, however, differs little in the two districts.

Table 2b includes also the mean monthly temperatures at Armagh, Belfast and Donaghadee for 1913,* and for the first two places also the differences from the normal values. It will be seen that the summer months of 1913, during which the majority of the results on which the present report is based were obtained, were about one degree cooler than normal; but notwithstanding this, precipitation was deficient, and sunshine of longer duration than average.

The moist equable climate and humid atmosphere of Ireland are peculiarly well fitted to the manufacturing processes involved in flax spinning and linen weaving, probably more so than any other part of the world where these trades are carried on.

WEAVING SHEDS.

COMPARISON OF COTTON AND LINEN WEAVING SHEDS.

With regard to construction and general arrangement of machinery, the linen weaving sheds of Ireland differ little from the cotton weaving sheds in the Lancashire district. Concrete- or double-roofed sheds, of which there were a number of instances in the cotton inquiry, did not exist, however, among the linen sheds investigated.

Detailed information relating to some typical sheds will be found in Table 3, and these may be compared with the particulars given on pages 44–49 of the Cotton Report.

It will be noticed from a comparison of linen with cotton weaving sheds that the capacity per loom is nearly twice as great in the former as in the latter, while the capacity per operative is about the same; in other words, although for a given number of looms linen weaving requires twice the number of operatives, yet the average floor space occupied by each loom and the head room above it are both greater, in consequence the workers of the two districts have about the same available air-space.

Few linen sheds contain more than 500 looms, but in the cotton trade sheds with as many as 1,000 or 2,000 looms are frequently met with.

The average maximum temperature attained daily in the sheds under observation during June, July, and August 1913, are detailed in Table 4, and for purposes of comparison equivalent values are given for the Lancashire sheds used in the experiments of 1910, and for one Lancashire shed during the summer 1913.

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* During the summers of 1912 and 1913 complete sets of daily observations were kindly supplied by Dr. J. L. E. Dreyer of the Armagh Observatory, Professor Moore and Mr. G. Robinson of Queen's University, Belfast, from the Observatory of the Donaghadee Coastguard Station, and Dr. H. G. Haworth of the Darwen Health Office. The thanks of the Committee are due to these gentlemen for their valuable co-operation.

TABLE 8.

DETAILS OF WEAVING SHEDS.

Shed	No. of Looms.	No. of Operatives.	Capacity (Cub. Ft.) Total	Per Loom.	Per Operative.	Aspect of Shed Lights.	Height in Feet. To underside of Valley	Maximum Head room.	Depth of Floor below Ground	Approximate Length of Shed	Approximate Breadth of Shed.	External Sources of Heat	Style of Weave.	Humidifying System	Ventilation	Approximate Length of Steam Pipes for Humidifying	Average Daily Maximum Temperature during Summer of 1913.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
							Ft. Ins.	Ft. Ins.	Ft. Ins.	Ft.	Ft.					Ft.	
"A" -	476	250	406,000	853	1,620	N	13 6	16 6	3 2	197	126	None	Cambrics -	Jets -	9–14 in. Pl. 1–18 in. Ex.	796	78 9°
"B"	248	110	320 000	1,290	2,916	N	11 3	18 9	—	153	105	Boiler House	Cambrics	Jets -	Never used	313	80 8°
"C"	90	47	104,000	1 160	2,220	N	12 7	21 3	—	166	58	None	Cambrics	Howorth's	34 in. diam. Plenum Fan	None	77 6°
"D"	69	36	80,600	1,170	2,240	N	11 6	18 10	—	88	60	Engine Room	Damask	None	None	None	—
"E"	270	135	246 090	911	1,820	N W.	12 8	21 6	—	162	82	Engine Room	Cambrics	Nield's -	Vanes according to conditions	None	79 3°
"F" -	465	255	359,000	772	1,410	E. & W.	18 ft. 0 in.*		—	200	178	None	Cambrics	Howorth's	6 ft. 0 in. Plenum	350	79 6°
"G"	291	150	270 000	928	1,800	N	12 3	17 9	—	230	70	None	Coarse and Fine Linens	Jets	1–18 in. Pl. 6–18 in. Ex.	1 100	82 2°
"H"	56	29	48,000	858	1 650	N	13 0	16 0	—	85	45	None	Coarse Linen	Jets -	2–18 in. Ex.	120	74 9°
"I"	198	100	166 000	865	1,660	N	12 3	18 6	—	141	76	None	Fine Linen Heavy Cotton	Hart's -	2–18 in. Ex.	—	—

* Flat Roof. Pl. (16) = plenum fans. Ex. = exhaust fans.

APPENDICES.

G 3

TABLE 4

AVERAGE MAXIMUM DAILY TEMPERATURES RECORDED IN EXPERIMENTAL WEAVING SHEDS

Temperatures in Degrees Fahrenheit.

Shed	1912. August			1912. September			1913. June			1913. July			1913. August			1913. Sum[illegible]		
	Inside Maximum Temperature.	Outside Mean Temperature.	Difference	Inside Maximum Temperature.	Outside Mean Temperature.	Difference	Inside Maximum Temperature.	Outside Mean Temperature.	Difference	Inside Maximum Temperature.	Outside Mean Temperature.	Difference	Inside Maximum Temperature.	Outside Mean Temperature.	Difference	Inside Maximum Temperature.	Outside Mean Temperature.	Difference
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
"A"	—	—	—	—	—	—	—	—	—	—	—	—	78·8	58·2	20·6	78·5	58·3	20·6
"B"	—	—	—	—	—	—	79·3	54·9	24·4	80·8	56·6	24·2	82·4	57·9	24·5	80·8	56·5	24·3
"C"	72·1	53·8	18·3	72·5	51·7	20·8	76·5	54·9	21·6	78·8	56·7	22·1	77·5	58·2	19·3	77·6	56·6	21·0
"E"	76·3	53·5	22·8	76·1	51·5	24·6	79·1	54·7	24·4	79·5	56·7	22·8	79·4	57·8	21·6	79·3	56·4	22·9
"F"	80·4	53·4	27·0	81·1	51·7	29·4	78·6	54·9	23·7	80·5	56·5	24·0	—	—	—	79·6	56·7	23·9
"G"	78·8	54·0	24·8	79·1	52·6	26·5	82·6	55·2	27·4	81·9	56·9	25·0	82·1	57·8	24·3	82·2	56·6	25·6
"H"	75·2	54·0	21·2	73·9	52·6	21·3	74·9	55·2	19·7	—	—	—	—	—	—	74·9	55·2	19·7
"I"	73·6	53·6	20·0	73·7	52·3	21·4	—	—	—	—	—	—	—	—	—	—	—	—
Mean	76·1	53·7	22·4	76·1	52·1	24·0	78·5	55·0	23·5	80·3	56·7	23·6	80·0	58·0	22·0	79·0	56·5	22·5
Comparison Cotton Shed in Lancashire in 1913	—	—	—	—	—	—	79·8	54·7	24·6	82·0	57·3	24·7	81·9	56·8	25·1	81·1	56·3	24·8
English Sheds (1910)	—	—	—	—	—	—	81·1	58·2	23·9	80·9	57·6	23·3	80·7	58·8	21·8	80·9	58·3	22·6

It will be noticed that the average maximum temperature attained in the Lancashire sheds during the summer months shown, was 80·9° F. for a mean outside temperature of 58·3° F., whilst the Irish sheds in August, for almost the same outside mean, reached on the average a maximum of 80·0° F., or nearly a degree less than the cotton sheds. It has already been pointed out that the summer in the North of Ireland is one degree cooler than that of Lancashire, from which it at once follows that the maximum summer temperatures of the Irish sheds will be almost two degrees below that of the cotton sheds.

It must however, be remembered that dry bulb temperatures are here referred to while the medical evidence suggests that wet bulb temperatures are of paramount importance. In many of the linen sheds it is usual to work with only two degrees between the wet and dry bulb whereas the Lancashire sheds in summer have often a difference of 4½ degrees. Compared by the wet bulb standard, therefore, the weaving sheds of the two countries reach maximum temperatures which for all practical purposes may be considered to be about the same.

SUMMER AND WINTER CONDITIONS.

Recording instruments were maintained for an entire year in three typical linen weaving sheds, one being rather warmer, another slightly cooler than the average. From the records obtained, two examples for each shed are reproduced in Figs. I., II. and III. The upper curves in each figure refer to an exceptionally hot week in summer, the lower to a cold period in winter.

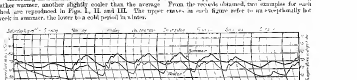


FIG. I.—*Summer and Winter Temperature Records in Shed "E."*

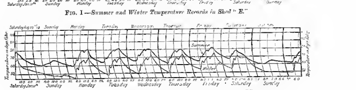


FIG. II.—*Summer and Winter Temperature Records in Shed "G."*

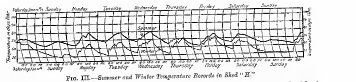


FIG. III.—*Summer and Winter Temperature Records in Shed "H."*

In each figure the thick line represents the dry bulb temperature in the shed during a hot summer week, and the fine line lying below it the temperature during a cold period in winter.

Fig. I. illustrates an average weaving shed with a mean maximum temperature in summer of 79·3° F., whilst Figs. II and III. are for sheds with summer temperatures of 82·2° F. and 74·9° F. respectively.

It will be seen that the temperature rises rapidly during the working hours; the two sharp indentations to be observed on the records for each day correspond to the cooling which occurs during meal hours.

The temperature usually reaches a maximum at the end of the afternoon, and drops rapidly when work ceases.

During the week end in winter there is in general an almost continuous drop of temperature until the steam is turned on on Monday morning. In summer the temperature falls rapidly during Saturday, but there is commonly a rise towards noon on Sunday.

For Shed "G" the summer records of temperature inside the shed are also reproduced above the corresponding outside temperatures (Fig. IV.).

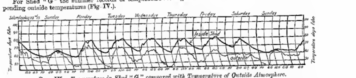


FIG. IV.—*Temperature in Shed "G" compared with Temperature of Outside Atmosphere.*

The thick line represents the dry bulb temperatures taken in the shed, the thin line the outside temperature.

Both curves rise rapidly between 6 a.m. and noon, and afterwards more slowly. At the end of the working day the shed is some 10 or 15 degrees hotter than the outside air. Both curves fall rapidly after 6 p.m., the shed cooling continuously until work starts next morning.

During Sunday afternoons, when the machinery is stopped, the shed is only 2 or 3 degrees above the outside temperature.

It will be noticed that at the end of the working day the shed is some 10 or 15 degrees above the outside temperature at that time, while the excess above the mean outside temperature is 20 or 25 degrees. Reference to Table 4, which gives the maximum inside and mean outside temperatures and their differences for the summer months for all sheds, shows an excess for the average shed of about 23 degrees.

A comparison between the inside and outside temperatures in winter would lead to similar results, except that now the distance between the two curves (*i.e.*, the excess of inside over outside temperature would be about half as great again. In Table 5 the monthly averages of the maximum temperatures reached daily in the three sheds referred to above are given from August 1912 to August 1913, both inclusive, and are compared with the corresponding monthly averages of outside mean temperatures.

TABLE 5.

MONTHLY AVERAGES OF MAXIMUM DAILY TEMPERATURES RECORDED IN THREE TYPICAL IRISH SHEDS.

Period.	Temperatures in Degrees Fahrenheit								
	Shed "E."			Shed "G."			Shed "H."		
	Average Inside Maximum Temperature.	Average Outside Mean Temperature.	Difference.	Average Inside Maximum Temperature.	Average Outside Mean Temperature.	Difference.	Average Inside Maximum Temperature.	Average Outside Mean Temperature.	Difference.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1912.									
August - - -	76·3	53·4	22·9	78·8	54·0	24·8	75·2	54·0	21·2
September - -	76·2	52·2	24·0	79·1	52·6	26·5	73·9	52·6	21·3
October - - -	74·9	47·0	27·9	76·1	47·4	28·7	71·6	47·4	24·2
November - -	73·9	43·8	30·1	75·0	43·9	31·1	71·1	43·9	27·2
December - -	72·3	43·2	29·1	74·7	43·4	31·3	69·6	43·4	26·2
1913.									
January - - -	71·2	40·2	31·0	74·3	40·1	34·2	70·7	40·1	30·6
February - -	72·1	41·9	30·2	74·8	42·2	32·6	70·5	42·2	28·3
March - - -	73·4	42·2	31·2	73·2	42·4	30·8	67·6	42·4	25·2
April - - -	74·9	46·0	28·9	75·9	46·3	29·6	73·0	46·3	26·7
May - - -	76·8	50·5	26·3	78·1	50·6	27·5	73·2	50·6	22·6
June - - -	79·1	54·7	24·4	82·6	55·2	27·4	74·9	55·2	19·7
July - - -	79·5	56·7	22·8	81·9	56·9	25·0	—	—	—
August - - -	79·4	57·8	21·6	82·1	57·8	24·3	—	—	—
Averages for summer months.	—	—	22·9	—	—	25·4	—	—	20·5
Averages for winter months.	—	—	30·8	—	—	32·5	—	—	28·0

In the summer months the difference between the two will be seen to vary from some 20½ degrees for Shed "H" a shed cooler than most, to 23 degrees for Shed "E," a typical shed, and 25½ degrees for Shed "G," which is one of the hottest sheds investigated. In winter months the corresponding differences become 28 degrees, 30 degrees and 32·5 degrees. The excess of inside over outside temperature, in fact, decreases steadily as the outside temperature rises.

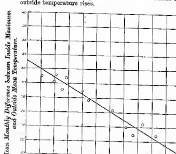


FIG. V.

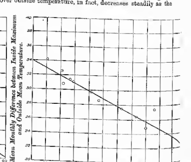


FIG. VI.

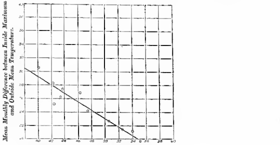


FIG. VII.

FIGS V., VI. AND VII.

Difference between Maximum Temperature in Shed and Mean Atmospheric Temperature Outside.

Fig. V. represents a shed of average temperature, Fig. VI. a hot, and Fig. VII. a cool shed. It will be noticed that in all cases, the hotter the weather, the smaller the temperature difference between the shed and the outside temperature.

It might at first appear that the artificial heating of the shed in winter is sufficient explanation of this fact, but the same thing occurs from day to day during the summer, when the shed rises only about 1 degree for 2 degrees rise in the outside temperature.

This will be seen in Figs. V., VI. and VII., where the mean monthly difference between inside and outside temperature (Table 5) are plotted as ordinates against the mean outside temperatures as abscissæ, Fig. V. referring to Shed "E," Fig. VI. to Shed "G." and Fig. VII. to Shed "H."

SHED CHARACTERISTICS.

From the above figures it can readily be deduced that, as was found to be the case for the Lancashire sheds, two degrees rise in the mean outside temperature, produces on an average, only one degree rise of the maximum shed temperature.

If, therefore, it is desired to compare two sheds, that is, to find a means of indicating that the one shed is relatively cooler or hotter than the other, it is necessary either to choose days when the outside temperature was the same in the neighbourhoods of the two sheds, and compare the inside maxima for those days; or alternatively to adopt the somewhat artificial method of subtracting from the maximum shed temperature half the outside mean temperature. The quantity thus obtained (inside maximum temperature—half outside mean temperature) shows no systematic variation with the outside temperature, but for any given shed is approximately constant (Table 6), and may be considered truly characteristic of the temperature conditions of the shed.

TABLE 6.

SHED "CHARACTERISTICS."

Period.	Shed "E."			Shed "G."			Shed "H."		
	Inside Maximum Temperature F.	Outside Mean Temperature F.	Shed Characteristic.	Inside Maximum Temperature F.	Outside Mean Temperature F.	Shed Characteristic.	Inside Maximum Temperature F.	Outside Mean Temperature F.	Shed Characteristic.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1912.									
August	76°·3	53°·4	49·6	78°·8	54°·0	51·8	75°·2	54°·0	48·2
September	76·2	52·2	50·1	79·1	52·6	52·8	73·9	52·6	47·6
October	74·9	47·0	51·4	76·1	47·4	52·4	71·6	47·4	47·9
November	73·9	43·8	52·0	75·0	43·9	53·0	71·1	43·9	49·1
December	72·3	43·2	50·7	74·7	43·4	58·0	69·6	43·4	47·9
1913.									
January	71·2	40·2	51·1	74·3	40·1	54·2	70·7	40·1	50·6
February	72·1	41·9	51·1	74·8	42·2	53·7	70·5	42·2	49·4
March	73·4	42·2	52·3	73·2	42·4	52·0	67·6	42·4	46·4
April	74·9	46·0	51·9	75·9	46·3	52·7	73·0	46·3	49·8
May	76·8	50·5	51·8	78·1	50·6	52·8	73·2	50·6	47·9
June	79·1	54·7	51·7	82·6	55·2	55·0	74·9	55·2	47·3
July	79·5	56·7	51·2	81·9	56·9	53·5	—	—	—
August	79·4	57·8	50·5	82·1	57·8	53·2	—	—	—
Mean Characteristic	—	—	51·2	—	—	53·0	—	—	48·4

NOTE.—The shed characteristic is obtained by subtracting half the outside mean temperature from the inside maximum temperature. It will be seen that the quantity thus obtained is nearly the same under all conditions in summer or winter. A high characteristic indicates a hot shed.

"Characteristics" for all the sheds investigated are given in Table 7, and the meaning becomes quite clear when it is remembered that, for example, Shed "F." of which the "characteristic" is 53·1, will on the average be 5 degrees hotter than Shed "C." whose "characteristic" is 48·1. The table includes the "characteristics" of some Lancashire sheds for comparison.

TABLE 7.

AVERAGE "CHARACTERISTICS" FOR IRISH AND ENGLISH SHEDS

Irish Sheds.				English Sheds.			
Shed.	"Characteristic"	Shed.	"Characteristic"	Shed.	"Characteristic"	Shed.	"Characteristic"
(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
"A"	49·9	"G"	53·0	"A"	51·5	"K"	56·2
				"B"	53·2	"L"	55·9
"B"	52·8	"H"	48·4	"C"	47·5	"M"	49·6
				"E"	50·0	"N"	48·9
"C"	48·1	"I"	49·7	"F"	52·2	"O"	50·6
				"G"	54·1		
"E"	51·2	Mean Characteristic	50·8	"H"	52·1	Mean Characteristic	51·8
"F"	53·1			"I"	50·7		
				"J"	52·5		

It is possible, from the numbers given in Table 7, to forecast with considerable accuracy the average maximum temperature of a shed for any month of which the mean outside temperature is known. The inside temperatures thus calculated are compared in Table 8 with those actually observed for Sheds "G," "H" and "E." and it will be noticed that the two figures rarely differ by more than a degree.

TABLE 8.

COMPARISON OF MEAN MONTHLY TEMPERATURES CALCULATED FROM "SHED CHARACTERISTICS" WITH OBSERVED TEMPERATURES.

Period.	Shed "E." "Characteristic" 51·2.				Shed "G." "Characteristic" 53·0.				Shed "H." "Characteristic" 48·4.			
	Outside Mean Temp.	Inside Max. Temp. Calculated.	Observed.	Diff.	Outside Mean Temp.	Inside Max. Temp. Calculated.	Observed.	Diff.	Outside Mean Temp.	Inside Max. Temp. Calculated.	Observed.	Diff.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Aug. 1912	53·4	77·9	76·3	1·6	54·0	80·0	78·8	1·2	54·0	75·4	75·2	0·2
Sept.	52·2	77·3	76·2	1·1	52·6	79·3	79·1	0·2	52·6	74·7	73·9	0·8
Oct.	47·0	74·7	74·9	−0·2	47·4	76·7	76·1	0·6	47·4	72·1	71·6	0·5
Nov.	43·8	73·1	73·9	−0·8	43·9	75·0	75·0	0·0	43·9	70·4	71·1	−0·7
Dec.	43·2	72·8	72·3	0·5	43·4	74·7	74·7	0·0	43·4	70·1	69·6	0·5
Jan. 1913	40·2	71·3	71·2	0·1	40·1	73·1	74·3	−1·2	40·1	68·5	70·7	−2·2
Feb.	41·9	72·2	72·1	0·1	42·2	74·1	74·8	−0·7	42·2	69·5	70·5	−1·0
March	42·2	72·3	73·4	−1·1	42·4	74·2	73·2	1·0	42·4	69·6	67·6	2·0
April	46·0	74·2	74·9	−0·7	46·3	76·2	75·9	0·3	46·3	71·6	73·0	−1·4
May	50·5	76·4	76·8	−0·4	50·6	78·3	78·1	0·2	50·6	73·7	73·2	0·5
June	54·7	78·5	79·1	−0·5	55·2	80·6	82·6	−2·0	55·2	76·0	74·9	1·1
July	56·7	79·5	79·5	0·0	56·9	81·4	81·9	−0·5	56·9	—	—	—
August	57·8	80·1	79·4	0·7	57·8	81·9	82·1	−0·2	—	—	—	—

The probable inside maximum temperature for any given day can be estimated in a similar manner by adding to the shed characteristic half the mean outside temperature for that day; but accidental weather changes or changes of condition now become more evident, and the values obtained will be less accurate than in the case of the monthly averages. A knowledge of the relation between inside and outside temperature, however, has an important bearing upon the analysis of the present observations, where it has enabled suitable corrections to be made when sheds are to be compared on days of slightly different outside temperature.

EFFECT OF SUNSHINE.

Apart from temperature, other meteorological elements such as duration of sunshine, amount of rain, direction and velocity of the wind, have their influence upon the temperatures reached in the sheds, and of these the first named proves most important. This sunshine effect is shown in Table 9, where the maximum shed temperatures are compared for continuously sunny and dull days respectively (chosen to be as nearly as possible of similar outside temperature).

TABLE 9.

Effect of Sunshine upon Maximum Temperature reached in Weaving Sheds.

I.—Sheds with Roofs not Whitewashed.

—	Outside Mean Temperature 50° F. to 55° F.			Outside Mean Temperature 55° F. to 60° F.			Outside Mean Temperature 60° F. to 65° F.			Average.	
	Inside Maximum Temperature.	Outside Mean Temperature.	No. of Hours Sunshine.	Inside Maximum Temperature.	Outside Mean Temperature.	No. of Hours Sunshine	Inside Maximum Temperature.	Outside Mean Temperature.	No. of Hours Sunshine.	No. of Hours Sunshine	Difference in Inside Maxima.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	°F.	°F.		°F.	°F.		°F.	°F.			
Shed "B"	79·8 74·5	53·0 53·0	10·6 0·1	84·2 76·6	57·9 55·6	10·4 0·0	88·5 80·4	61·8 61·2	10·6 0·5	— —	— —
Difference	5·3	0·0	10·5	7·6	2·3	10·4	8·1	0·6	10·1	—	—
*Difference corrected	5·3	—	—	6·4	—	—	7·8	—	—	10·3	6·5
Shed "C" (before whitewashing.)	— —	— —	— —	82·6 74·2	58·5 54·2	11·3 0·3	— —	— —	— —	— —	— —
Difference	—	—	—	8·4	4·3	11·0	—	—	—	—	—
*Difference corrected	—	—	—	6·2	—	—	—	—	—	11·0	6·2
								Average		10·6	6·4

Conclusion.—*If the roof of a shed is not whitewashed—*
10·6 hours of sunshine will raise its temperature by 6·4 degrees.
Or each hour of sunshine will raise its temperature by 0·6 degree.

II.—Sheds with Whitewashed Roofs.

	°F.	°F.		°F.	°F.		°F.	°F.			
Shed "A"	— —	— —	— —	80·2 77·4	56·6 †62·7	9·9 0·4	— —	— —	— —	— —	— —
Difference	—	—	—	2·8	− 6·1	9·5	—	—	—	—	—
*Difference corrected	—	—	—	5·8	—	—	—	—	—	9·5	5·8
Shed "C" (after whitewashing)	— —	— —	— —	78·8 76·2	56·8 59·0	10·7 0·3	— —	— —	— —	— —	— —
Difference	—	—	—	2·6	− 2·2	10·4	—	—	—	—	—
*Difference corrected	—	—	—	3·7	—	—	—	—	—	10·4	3·7
Shed "E"	80·3 76·6	53·4 53·0	10·6 0·2	81·9 77·0	57·5 56·9	11·0 0·1	83·3 78·7	60·9 61·5	10·1 0·3	— —	— —
Difference	3·7	0·4	10·4	4·9	0·6	10·9	4·6	− 0·6	9·8	—	—
*Difference corrected	3·5	—	—	4·6	—	—	4·9	—	—	10·4	4·3
Shed "G"	80·3 78·8	53·6 54·0	9·4 0·1	84·2 79·7	57·6 57·2	10·3 0·4	86·5 83·6	62·0 62·8	10·6 0·2	— —	— —
Difference	1·5	− 0·4	9·3	4·5	0·4	8·9	2·9	− 0·8	10·4	—	—
*Difference corrected	1·7	—	—	4·3	—	—	3·3	—	—	9·9	3·1
Shed "H"	— —	— —	— —	77·9 73·2	57·7 55·0	9·9 0·4	— —	— —	— —	— —	— —
Difference	—	—	—	4·7	2·7	9·5	—	—	—	—	—
*Difference corrected	—	—	—	3·3	—	—	—	—	—	9·5	3·3
								Average		10·0	4·0

* *The difference between the shed maxima on sunny and sunless days is corrected for any difference of the mean outside temperature in the two cases, by making use of the fact that one degree rise in the outside temperature produces half a degree rise inside the shed.*

† Note.—*For this shed no observations were available for sunless days when the outside mean was below 60° F.*

Conclusion.—*If the roof of a shed is whitewashed—*
10·0 hours of sunshine will raise its temperature by 4·0 degrees.
Or each hour of sunshine will raise its temperature by 0·4 degree.

It will be seen that in the case of an ordinary dark roof, 10 hours' sun adds 6 degrees to the inside temperature (by radiation alone, and apart from the fact that sunny days are usually hot). For a whitewashed roof, 10 hours' sun adds only 4 degrees. These figures may be verified by comparing directly the temperatures reached in Shed "C" before and after whitewashing the roof, when it is found that on continuously sunny days the shed was some 3 degrees hotter (for similar outside temperatures) before its roof was whitewashed. For dull days the effect is negligible.

Direct readings on a sunny day of a thermometer placed respectively under a whitewashed and ordinary unwhitewashed slate average two or three degrees less in the former case.

The relations between shed temperatures and the outside meteorological conditions were fully discussed in the Cotton Report (page 36, Table 7) when it was shown that they could be represented by a mathematical expression.*

Roof Sprays.

In whitewashing a shed roof the object in view is to reflect a proportion of the solar heat radiation. A thin layer of water spread over the roof surface will absorb the heat rays, and if this film is continually renewed the heat will be carried away. Thus, although the shed is protected from the heat of the sun's rays in either case, the physical processes involved are entirely different.

In addition to its absorptive powers a layer of water will produce an active cooling due to its evaporation and specific heat. As, however, the quantity of water used is small, the second factor is usually unimportant, but evaporation is effective whenever the outside air is dry and especially in strong dry winds.

In the discussion of the cotton weaving investigations it was shown that the maximum effect of roof sprays was some 6 degrees, the average about 2·8 degrees. Similar experiments were repeated during the course of the present work on one Irish shed and the results which are detailed in Table 10 show a cooling effect due to the sprays which on sunny days amounte to about 2 degrees but on dull days is inappreciable. In the case of this shed, therefore, the recorded effect was not greater than that obtained by whitewashing.

TABLE 10.

Effect of Roof Sprays. Shed "B."

Date.	Sprays on			Date.	Sprays not on		
	Hours Sun.	Max. inside Temperature.	Mean outside Temperature.		Hours Sun.	Max. inside Temperature.	Mean outside Temperature.
Sunny Days.				*Sunny Days.*			
July 1	14·6	83·8	57·6	June 16	11·4	87·5	59·6
" 3	8·8	83·0	60·9	" 17	10·6	88·5	61·8
" 22	12·0	81·4	58·0	" 30	13·8	85·8	58·6
" 23	14·0	81·4	56·8	July 7	10·8	81·0	52·4
" 24	10·4	81·4	54·8	August 4	7·0	84·2	58·0
" 25	7·0	83·2	57·6	" 11	8·1	81·0	55·0
" 31	9·8	81·0	57·5				
August 18	13·0	82·6	57·5				
" 19	12·6	83·8	54·0				
" 25	10·8	83·7	60·0				
" 26	7·5	83·8	58·5				
" 27	8·5	84·0	59·2				
Average	10·8	82·7	57·7	Average	10·3	84·7	57·6
Dull Days.				*Dull Days.*			
July 2	4·2	81·9	59·1	June 20	1·1	79·7	56·4
" 4	1·6	78·3	56·0	" 27	3·1	79·5	55·0
" 28	0·8	81·5	56·8	August 5	1·7	81·0	52·4
" 29	0·0	84·0	59·0	" 15	0·7	85·4	66·2
August 1	3·8	84·4	61·3				
" 6	4·8	80·0	53·6				
" 7	3·7	83·0	55·1				
" 29	1·7	80·6	58·6				
Average	2·6	81·7	57·4	Average	1·6	81·4	57·5

Conclusion.—*On sunny days sprays make shed 2·0° cooler, although outside sunshine is 0·5 hour greater, therefore, the cooling effect of the sprays amounts to about 2·3°. On dull days sprays have no appreciable effect.*

Variation of Temperature during the Day.

The external conditions which affect the maximum temperature reached by a weaving shed have been given in outline above.

The rise during the day is not uniform but is rapid in the morning and slow in the afternoon (see Figs. I., II., III., IV.). Table 11 gives the rates of temperature rise, in degrees F. per hour, for the three periods (1) before breakfast, when the rate of rise averages about 3 degrees per hour, (2) between breakfast and dinner, with a rise of some 2 degrees per hour, and (3) after dinner when the rise is less than 1 degree per hour. The corresponding values for the Lancashire sheds were 3·7, 1·8, and 1·2 degrees per hour, and therefore slightly higher than the Irish figures.

* i.e., $t = A + \frac{\theta}{2} + ch$.

Where "t" is the inside maximum temperature, A a constant = about 48, h the number of hours' sunshine, c a constant = 0·4 for a whitewashed and 0·6 for an ordinary roof, and θ the mean outside temperature.

TABLE 11.

RATES OF TEMPERATURE RISE IN IRISH WEAVING SHEDS

Shed	Rate of Rise of Temperature in ° F per Hour.											
	June 1913.			July 1913.			August 1913			Summer 1913.		
	Period I.	Period II.	Period III.	Period I.	Period II.	Period III.	Period I.	Period II.	Period III.	Period I.	Period II.	Period III.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
"A" . . .	—	—	—	—	—	—	2·4	2·1	2·0	2·4	2·1	1·0
"B" . . .	3·0	1·8	0·5	3·0	1·7	0·7	3·1	1·9	0·7	3·0	1·8	0·6
"C" . . .	2·7	2·0	0·5	3·1	1·8	0·7	3·1	1·6	0·7	3·0	1·8	0·6
"E" . . .	2·6	1·8	1·1	2·7	1·7	1·0	2·6	1·6	0·8	2·6	1·7	1·0
"F" . . .	4·3	2·7	1·4	4·1	2·6	1·4	—	—	—	4·2	2·7	1·4
"G" . . .	3·7	2·3	1·0	3·4	2·2	0·9	3·4	2·4	0·8	3·5	2·3	0·9
"H" . . .	2·0	1·5	0·7	—	—	—	—	—	—	2·0	1·5	0·7
Averages .	3·0	2·0	0·9	3·3	2·0	0·9	2·9	1·9	0·8	3·0	2·0	0·9

NOTE.—*In the above table the working day is divided into three periods* :—

I. Before the breakfast interval (usually 6 a.m. to 8 a.m.).

II. Between breakfast and dinner (usually 9 a.m. to 1 p.m.).

III. After dinner (usually 2 p.m. to 6 p.m.)

It is evident that any means adopted to cool the shed, such, for instance, as increased ventilation, should be set in operation at the beginning of the working day.

Although the artificial ventilation is interrupted during meal hours, there is still in a weaving shed a fall of temperature during these periods.* The average rate of fall is 1·0° per hour during the breakfast interval, 1·3° per hour during the dinner interval, and 3·3° per hour at the end of the working day. The individual figures, however, vary considerably from shed to shed, especially during the meal hours. Extreme cases are illustrated by Shed "B" with no cooling during the breakfast interval, and Shed "F" with a drop of almost 3° per hour. All sheds, however, show a rapid temperature decrease at the end of the day after work is stopped. (*See* Table 12.)

TABLE 12.

RATES OF TEMPERATURE DECREASE IN IRISH SHEDS DURING MEAL TIMES.

Shed.	Fall of Temperature in ° F. per Hour.											
	June, 1913.			July, 1913.			August, 1913.			Summer, 1913		
	Breakfast Interval.	Dinner Interval.	End of Working Day.	Breakfast Interval.	Dinner Interval.	End of Working Day.	Breakfast Interval	Dinner Interval	End of Working Day.	Breakfast Interval	Dinner Interval	End of Working Day.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
"A" .	—	—	—	—	—	—	0·3	0·4	3·3	0·3	0·4	3·3
"B" .	0·2	0·4	3·9	—0·2	0·1	3·7	—0·3	0·4	3·6	—0·1	0·3	3·7
"C" .	0·6	0·8	2·0	0·9	1·1	3·3	0·7	0·7	2·0	0·7	0·9	2·1
"E" .	1·1	1·3	3·5	1·4	1·1	3·2	1·1	0·5	2·5	1·2	1·0	3·1
"F" .	2·7	3·0	5·0	2·8	3·0	4·8	—	—	—	2·8	3·0	4·9
"G" .	2·1	2·7	3·9	1·6	2·4	3·6	1·7	2·4	3·3	1·8	2·5	3·6
"H" .	0·4	1·0	2·7	—	—	—	—	—	—	0·4	1·0	2·7
Average .	1·2	1·5	3·5	1·3	1·5	3·5	0·7	0·9	2·9	1·0	1·3	3·3

It will be noticed that the hottest sheds in which the temperature rises quickly, also cool rapidly, and an extension of the meal hours would materially reduce the maximum temperatures attained, especially if arrangements were made to maintain the ventilation during these periods.

DISTRIBUTION OF TEMPERATURE IN A WEAVING SHED.

In a large weaving shed it frequently happens that a temperature gradient, due to some such structural feature as an adjacent boiler-house or engine-room, is maintained from end to end of the room. The gradient will vary from day to day as the direction of the wind alters. It will be reduced by a current from the hot to the cold end of the shed and increased by a current in the reverse direction. Fig. VIII., which refers to a shed having an engine-room at its south-east end, illustrates such an effect.

* In flax-spinning mills the temperature rises.

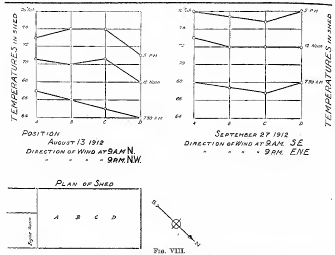


FIG. VIII.

Temperature Distribution in a Weaving Shed.

Shed "E.," which is shown in plan, has an engine room on the S.E. side, which maintains a temperature gradient throughout the shed. During two months of the summer, 1912, the manager of this shed had daily wet and dry bulb readings taken from thermometers placed at the positions marked A, B, C., D., on the plan.

The curves shown in the figure represent the readings taken on two days. It will be noticed that when a S.E. wind is blowing, the cool outside air filters into the hot end of the shed, and tends to equalise the temperature.

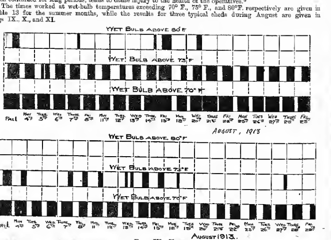
When a north-west wind is blowing, the end of the shed which adjoins the boiler-house is some 3° hotter than the other end, while during south-east winds the temperature along the shed is equalised.

Apart from this general variation of temperature along the shed, there is, quite near to the outside walls, a local cooling by which in cold weather considerable condensation is often produced.

TIME WORKED AT HIGH TEMPERATURES.

It will be seen from the medical evidence that work carried out at high wet-bulb temperatures, especially when continued for long periods, tends to cause injury to the health of the operatives.*

The times worked at wet-bulb temperatures exceeding 70° F., 75° F., and 80°F. respectively are given in Table 13 for the summer months, while the results for three typical sheds during August are given in Figs IX., X., and XI.



FIGS. IX., X.

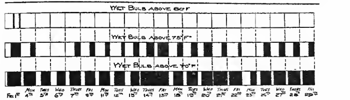


FIG. XI.

Time worked above 70° F., 75° F., and 80° F. Wet Bulb Temperature.

The diagrams show the temperature conditions in three sheds during the month of August, 1913. Fig. IX. illustrates a hot, Fig. X. a cool, and Fig. XI. an average shed.

The length of a strip represents the total number of working hours during this month. The dates are given at the bottom of the figure.

In the first strip all the hours during which the wet bulb temperature was above 70° F., have been blacked out, and it will be seen for instance, that on the 7th, the hottest shed was below 70° F. only two hours in the morning, and exceeded 75° F. for more than half the day.

The other strips give in the same way the number of hours worked above 75° F. and 80° F.

It will be noted that Saturdays and Sundays have not been included in the diagrams.

TABLE 13.

PERCENTAGE OF TIME IN IRISH SHEDS WORKED ABOVE GIVEN WET BULB TEMPERATURES.

Shed Index.	June.				July.				August.				Summer.			
	I.	II.	III.	All Day	I.	II.	III.	All Day	I.	II.	III.	All Day.	I.	II.	III.	All Day.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Wet Bulb above 70° F.																
"A" - -	—	—	—	—	—	—	—	—	3	44	100	58	3	44	100	58
"B" - -	6	62	99	87	4	92	100	77	10	97	100	80	7	84	100	75
"C" - -	2	37	74	45	4	68	94	66	5	57	100	64	4	54	89	58
"E" - -	8	65	95	85	18	81	100	76	13	80	100	74	12	74	98	71
"F" - -	3	48	86	54	10	67	96	67	—	—	—	—	7	58	91	61
"G" - -	19	83	100	79	13	88	100	80	15	86	100	79	16	85	100	79
"H" - -	0	32	68	38	—	—	—	—	—	—	—	—	0	32	68	38
Average -	6	54	87	58	9	79	98	73	9	73	100	71	7	62	92	63
Wet Bulb above 75° F.																
"A" - -	—	—	—	—	—	—	—	—	0	3	57	24	0	3	57	24
"B" - -	0	16	45	24	0	29	86	46	0	47	100	59	0	31	77	43
"C" - -	0	14	29	17	0	17	66	33	0	3	37	16	0	11	44	22
"E" - -	0	12	56	27	0	12	64	31	0	10	77	35	0	11	66	31
"F" - -	0	16	46	24	0	25	69	38	—	—	—	—	0	21	58	31
"G" - -	0	38	91	54	0	41	88	53	0	41	98	56	0	40	92	54
"H" - -	0	0	22	9	—	—	—	—	—	—	—	—	0	0	22	9
Average -	0	18	48	26	0	25	75	40	0	21	74	38	0	17	59	31
Wet Bulb above 80° F.																
"A" - -	—	—	—	—	—	—	—	—	0	0	2	1	0	0	2	1
"B" - -	0	4	25	11	0	0	23	9	0	2	40	17	0	2	29	12
"C" - -	0	0	17	7	0	0	6	2	0	0	0	0	0	0	8	3
"E" - -	0	0	16	8	0	0	9	4	0	1	1	1	0	0	9	4
"F" - -	0	0	16	6	0	2	19	9	—	—	—	—	0	1	18	8
"G" - -	0	6	36	17	0	2	32	14	0	4	20	9	0	4	29	13
"H" - -	0	0	0	0	—	—	—	—	—	—	—	—	0	0	0	0
Average -	0	2	18	8	0	1	18	8	0	1	13	6	0	1	14	8

N.B.—The numbers in the above table indicate the percentage of each period of the days in the summer months, during which the wet bulb thermometer exceeded 70° F., 75° F., 80° F. respectively. Periods I., II. and III. are in most cases 6 a.m. to 8 a.m., 9 a.m. to 1 p.m., 2 p.m. to 6 p.m., and the last column for each month gives the percentage of the total time worked above the given wet bulb temperatures. Combined results for the summer are also given. Saturdays are not included.

To take an example: It will be seen from the table that Shed "G." in July is always below 75° F. wet bulb in Period I., i.e., before breakfast. In period II., i.e., between breakfast and dinner, it works 41 per cent. of the time (or 1¾ out of 4 hours) above 75° F., wet bulb, while in Period III., i.e., after dinner, it is 88 per cent. (or 3½ out of 4 hours) above 75° F. wet bulb. The total time worked above 75° F. wet bulb during the average day for this shed is therefore 5¼ hours or 53 per cent. of the 10 hour working day, as given in the last column for July.

All numbers were obtained from analysis of the continuous records taken in the various sheds.

It is evident from Table 13 that in summer, in the average shed, the time spent above 70° F. wet bulb is about 60 per cent., above 75° F. about 30 per cent., and above 80° F. about 5 per cent. of the total. The corresponding figures for the hottest shed are 79, 54, and 13 per cent.

It has been observed that the sheds become progressively hotter as the day advances, and Table 13 indicates that practically all sheds are above 70° F wet bulb during the entire after-dinner period, that the hottest sheds are above 75° F. for about nine-tenths of this period, and above 80° F. for about a third of this period.

Time Worked at Low Temperatures.

In the evidence given by operatives* a number of complaints were made with regard to the discomfort experienced in the early hours of cold winter days. To ascertain the actual conditions, the automatic temperature records taken in three sheds were analysed. The daily records obtained in summer and in winter were similar in general character to those reproduced in Figs. I., II., and III. It will be noticed that as soon as work is stopped the temperature of the shed decreases rapidly, and continues to decrease until the early hours of the next morning, when the fall is checked in summer by the sunrise, and in winter by the artificial heating, which is usually begun about an hour before the commencement of the day's work. In Table 14 the average minimum temperatures and the average temperatures at the time when the shed starts work are given for Sheds "G," "H," and "E."

TABLE 14.

Average Monthly Minimum Temperatures.

Period.	Shed "E." Average Minimum Temperature in Shed.	Shed "E." Average Temperature at beginning of Work.	Shed "E." Difference.	Shed "G." Average Minimum Temperature in Shed.	Shed "G." Average Temperature at beginning of Work.	Shed "G." Difference.	Shed "H." Average Minimum Temperature in Shed.	Shed "H." Average Temperature at beginning of Work.	Shed "H." Difference.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1912.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
September	61·7	61·7	0·0	60·8	62·2	1·4	61·8	62·0	0·2
October	60·0	62·7	2·7	57·0	59·7	2·7	58·2	59·6	1·4
November	59·8	62·1	2·3	54·8	58·3	3·5	54·7	58·9	4·2
December	56·4	61·8	5·4	53·2	58·6	5·4	52·4	56·8	4·4
1913.									
January	56·3	62·1	5·8	52·5	57·5	5·0	54·1	57·7	3·6
February	57·0	63·2	6·2	53·0	56·9	3·9	54·3	57·2	2·9
March	56·4	62·9	6·5	51·0	53·6	2·6	51·3	54·5	3·2
April	58·0	60·2	2·2	54·9	65·6	1·7	55·2	58·1	2·9
May	62·0	63·3	1·3	59·2	60·6	1·4	59·5	61·1	1·6
June	65·2	65·2	0·0	64·1	65·4	1·3	62·6	63·2	0·6
July	66·2	66·2	0·0	64·1	65·7	1·6	65·6	65·7	0·1
August	66·5	66·5	0·0	64·6	66·1	1·5			—
Mean Difference (Summer)	—	—	0·0	—	—	1·5		—	0·8
Mean Difference (Winter)	—	—	6·2	—	—	3·8			3·3

Note.—*The mean difference between the average minimum temperature in the sheds and the average temperature when work starts is 0·8 in summer and 4·4 in winter.*

These figures show that the temperatures are in winter raised some four or five degrees above the minimum before work begins and as the rate of rise in the early working hours is extremely rapid, there appears to be no valid reason why a comfortable temperature should not be easily attained.

Analysing the records for the working periods we find that in an average shed in winter the time spent below 52° F. is less than 1 per cent. of the total, below 57° F. 3 per cent., and below 62° F. 13 per cent. In other words this implies that the temperature is below 57° F for about a quarter of an hour each morning. The actual values are given in Table 15 and illustrated by Fig. XII. which shows a typical shed for the month when the morning temperatures were lowest (March).

TABLE 15.

Shed.	Winter, 1913: Percentage Time Worked below: 52° F. Dry Bulb Period I.	52° F. Period II.	52° F. Period III.	52° F. All.	57° F. Dry Bulb Period I.	57° F. Period II.	57° F. Period III.	57° F. All.	62° F. Dry Bulb Period I.	62° F. Period II.	62° F. Period III.	62° F. All.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
"E"	0	0	0	0	1	0	0	0	10	0	0	2
"H"	2	0	0	0	15	1	0	4	52	8	0	12
"G"	2	0	0	0	26	3	0	6	69	24	3	24
Average	1	0	0	0	14	1	0	3	44	11	1	13

Note.—*In the above table the working day is divided into three periods:—*
I. Before the breakfast interval (usually 6 a.m. to 8 a.m.).
II. Between breakfast and dinner (usually 9 a.m. to 1 p.m.).
III. After dinner (usually 2 p.m. to 6 p.m.).

* See Minutes of Evidence, Qq. 2868 ff, 3093–100.

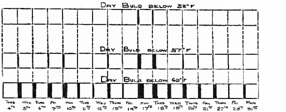


FIG. XII.

Time worked below Dry Bulb Temperatures of 52° F., 57° F., and 62° F. in a Weaving Shed.

The diagram shows the conditions in a weaving shed during the month of March, 1913, most sheds reaching their lowest temperatures in this month.

The length of a strip represents the total number of working hours (excluding Saturdays) during the month. The dates are given at the bottom of the figure.

In the lowest strip all the hours during which the temperature was below 62° F. dry bulb have been blacked out and it will be seen that on the 7th, for instance, this shed was below 62° F. for about two-and-a-half hours in the morning.

The other strips give in the same way the number of hours worked below 57° F. and 52° F.

HUMIDITY.

Hygrometer records were taken in a number of weaving sheds and selections from these humidity charts which represent the conditions during August are reproduced in Figs. XIII, XIV., XV. for Sheds "F," "G," and "E" respectively.

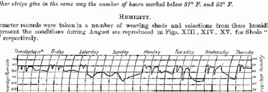


FIG XIII.

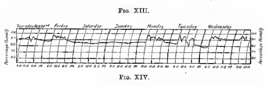


FIG. XIV.

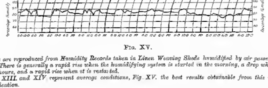


FIG. XV.

These are reproduced from Humidity Records taken in Linen Weaving Sheds humidified by air passed over hot water. There is generally a rapid rise when the humidifying system is started in the morning, a drop when it stops at meal hours, and a rapid rise when it is restarted.

Figs. XIII. and XIV represent average conditions, Fig XV. the best results obtainable from this method of Humidification.

The first two sheds are typical of ordinary practice. The humidity, which is very variable, shows a sharp increase when the steam is turned on in the morning and drops considerably during the meal hours. The average degree of moisture is slightly below that which the Act allows, but on individual occasions the legal limit is exceeded.

Fig XV. (Shed "E") gives a week's records from the series taken in a shed where the humidifying apparatus is regulated with exceptional care and skill and probably represents the most uniform working conditions obtainable.

All three sheds were humidified by means of ducts leading from conditioning apparatus of an ordinary type.

In Fig. XVI. records are given for Shed "H" in which steam jets are used. The variations here are very erratic, for it is difficult to maintain even approximately constant conditions with steam jets which, however, enable the percentage moisture to be rapidly altered if desirable.

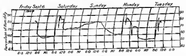


FIG. XVI.

Fig. XVI. is a record of humidity taken in a Linen Weaving Shed humidified by steam jets. Where steam jets are used it is possible to produce rapidly very large alterations in humidity.

In this case the humidity rises in the morning from 60 per cent. to 90 per cent. in less than an hour.

On the other hand, unless continual attention is paid to the apparatus, the humidity is very variable.

Figs. XVII. and XVIII. illustrate the variations of humidity in cotton weaving sheds, the former referring to common practice, the latter to a shed which derived its moisture from the evaporation of cold water; in this case very rapid changes of moisture cannot be produced

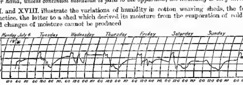


FIG. XVII.

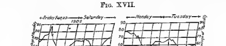


FIG. XVIII.

Fig. XVII. represents average hygrometric conditions in a Cotton Weaving Shed which was humidified through a trunk system.

Fig. XVIII. is a humidity record taken in a cotton shed in which the only source of humidity was that derived by passing the ventilating air over surfaces moistened by cold water.

In this case no sudden variations occur or can be produced, but there is a continual decrease in humidity through the working day; for while the shed is cool, sufficient moisture is brought in to produce relatively high humidities, but as the shed gets gradually hotter the supply of moisture becomes insufficient.

Finally, Fig. XIX. is a record taken in a "*dry*" damask shed where the absolute quantity of moisture is nearly constant and the variations in percentage humidity are due principally to changes of temperature.

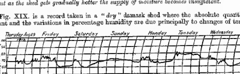


FIG. XIX.

Fig. XIX. illustrates the humidity conditions in a weaving shed where artificial humidification is not used.

It will be noticed that the maximum humidity attained during this period is about 80 per cent. The variations are due rather to temperature changes than to alterations in the absolute amount of moisture present.

Generally speaking, the temperature of the dry sheds is rather lower than that of the wet sheds, and the humidity averages 65 per cent. or 75 per cent. as compared with 90 per cent. Recording instruments were run in Shed "D" during August and September, 1912. The average maximum temperatures were 71·2° F. and 70·4° F. or about five degrees lower than the wet sheds under observation during the same period. The temperature record for a typical week in August, 1912, is reproduced in Fig. XX. which also shows a record of the outside temperature and of the temperature in the coolest end hottest wet shed.

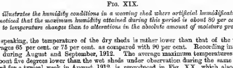


FIG. XX

Comparison of Temperature Records in Wet and Dry Sheds.

Records are reproduced for a summer week in shed "D" where no artificial humidification is used, while the corresponding records for a hot wet shed "F" and a cool wet shed "C" are also included. The lowest curve represents the outside temperature record for this period.

It will be noticed that at the end of the working day, the dry shed "D" is some 10 degs. cooler than shed "F" and about 2 degs. cooler than shed "C."

Variation of Humidity with Position in Shed.

The variation of humidity in different parts of a shed was studied by taking readings from four psychrometers placed at equal distances from each other along the centre line of a shed 160 ft. in length. All the thermometers were read three times a day for two months. The humidifying apparatus was regulated with respect to one of the central psychrometers, the difference between the wet and dry bulbs being kept as nearly as possible to the limit allowed by the Act. Of the five hundred double readings thus taken only two indicated a difference of more than $2\frac{1}{2}$ degrees and twenty-seven a difference of less than $1\frac{1}{2}$ degrees, between the wet and dry bulb temperatures.

It is therefore clear that given satisfactory construction and careful regulation the humidity in a shed can be kept within close limits. It should be noted, however, that the instruments used were placed well away from the walls and their positions selected so that the readings should represent accurate hygrometric conditions in a given part of the shed. As pointed out by Sir Henry Cunningham,* an instrument placed in an unsatisfactory position will give unreliable results.†

Sources of Heat.

We have investigated above the conditions commonly existing in the Irish linen sheds with regard to temperature and humidity, and it is evident that excessive temperatures are frequently attained during the summer months.

In order to discuss rationally means of reducing the temperature of the sheds it is necessary to consider separately the various ways by which heat passes in and out of a shed.

The sources of heat in a weaving shed may be enumerated as follows:—

(1) The power supplied to the shed.
(2) The heat radiated from the steam pipes.
(3) The bodily heat of the operatives.
(4) The radiant heat of the sun.
(5) Accidental sources, such as an adjacent boiler-house or engine-room.

The heat thus introduced causes the temperature of the shed to rise above that of the outside atmosphere, and the rise continues until the thermal outflow balances the inflow; this equilibrium is usually attained towards the end of the working day (see Figs. I., II., and III.)

The heat introduced into a shed is disposed of in three different ways—

(1) It is carried away by the air used for ventilation.
(2) It is absorbed as latent heat by the evaporation of any water used for humidification.
(3) It is carried away by conduction through the walls, floor, and roof.

It is obvious that the temperature of the shed can only be reduced either by diminishing the heat supplied or by increasing the heat carried away, and we will therefore discuss each item in turn.

Power.—The power supplied varies from one-third to two-thirds of a horse-power per loom, and amounts to one-half or two-thirds of the total heat introduced.‡ Any improvement in power transmission or loom construction will reduce the source of heat while producing economic advantages which many will consider of still greater importance. A discussion of power economy would lead us beyond the scope of the present report, but improvement of the plant would be possible in many of the mills. Old and worn out machinery is occasionally kept working when conditions of economy would have suggested its replacement by newer and more efficient plant. Further, the loom manufacturers, pressed by the necessity of producing machinery at a minimum cost, have somewhat neglected the question of power economy. It should be remembered that where any machinery is in continual use, a slight improvement in this respect will in the course of a single year cover a considerable difference in capital cost.

Steam Pipes.—In the report on cotton weaving the question of the heat radiated from steam pipes was considered at some length§ and it was shown that by covering the pipe with a lagging of fair quality, the heat loss could be reduced to less than one-fifth that from a bare pipe. The new Regulations introduced since the issue of this report have led to considerable improvements in pipe covering. There are at present more than fifty different laggings which have been certified as having an efficiency of 80 per cent. or over. An efficient lagging will result in the reduction of the shed temperature, but its use could be justified by purely economic considerations.

Bodily Heat of Operatives.—The bodily heat from an adult has been given as 300 or 900 B.T.U. per hour according to the clothing worn, amount of work done, &c.; about 500 B.T.U. probably corresponds to the conditions here dealt with.

In a shed where the other sources of heat are minimised the bodily heat of the operatives may account for one-sixth of the total; in a hot shed it will be relatively unimportant.

Radiant Heat of the Sun.—From what has been said above (pp.) this may account for a rise of 6 degrees at the end of the day and it is therefore important that all roofs should be efficiently whitewashed during the summer months.

Accidental Sources of Heat.—In some mills the engine room or boiler house is adjacent to the weaving shed. This arrangement causes an additional and continuous influx of heat and is apt to result in an uneven distribution of humidity; for both reasons it is undesirable. In planning a factory the difficulty can be avoided by separating the boiler house from the shed by an open alley way.

Efflux of Heat.

We must now consider the various ways in which the heat may escape from the shed.

Heat carried away by the ventilating air.—This is measured by volume used and by the difference between the temperature of the incoming air and that in the shed. In many factories the air is humidified by passing it over hot water or through hot sprays before it enters the shed and under such conditions it is practically ineffective as a cooling agent.||

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* Second Report of the Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds [Cd. 5566], 1911, Appendix XIV.

† It will in fact be found that close to an outside wall the air is generally saturated; in winter the cooling being in some positions sufficient to produce supersaturation and condensation.

‡ Some difficulties have been encountered by those engaged in the textile trades in realising that the loom or frame, although apparently cool, is at the same time dissipating a large quantity of heat to the atmosphere of the room. The following rough calculation may be of help. Taking a loom as requiring one-third of a H.P. to run, and as presenting a surface of, say, 36 square feet to the atmosphere (a probable underestimate), it is necessary for the machine to dissipate

$$\frac{33000 \times 60}{3 \times 774} = 850 \text{ B.T.U. per hour.}$$

Experiment has shown that in still air a metal surface loses heat at the rate of 3 B.T.U. per square foot per hour per degree temperature difference between the metal and the surrounding atmosphere. When the atmosphere is in motion the amount will be much greater. Using this figure then, it will be seen that a temperature difference of at most 8 degrees is required in order to get rid of 850 B.T.U. per hour. It is, of course, well known that, owing to its high conductivity a metal surface at the same temperature as the surrounding objects feels cold to the touch, and a metal surface only 8 degrees above the temperature of the room will not feel warm.

§ Report of Departmental Committee on Humidity and Ventilation in Cotton Weaving Sheds [Cd. 5566], 1911.

|| *See* Fig. XXIII., page 69.

A comparison between Shed "B" in which no artificial ventillation is used and Sheds "C," "E," "F," where the above system of ventilation is in operation, bears out this assumption under working conditions.

From Table 4 we see that the average maximum temperature for summer is 80·8° F. for Shed "B," and 77·6° F., 79·3° F., 79·6° F. for Sheds "C," "E," "F" respectively.

Theoretically it would be possible to maintain a difference of two degrees between the wet and dry bulbs in the shed by admitting saturated air at about 4 degrees below the shed temperature: actually as some of the moisture is lost by absorption in the warps and convection to the outside, the temperature of the incoming air must approach closely that of the shed. Even with 4 degrees between the air and the shed temperatures the cooling effect is unimportant. Few sheds have a ventilating plant of capacity of more than 500,000 cubic feet per hour and with air at 4 degrees below the shed temperature this corresponds to removing about $3 \cdot 6 \times 10^4$ B.T.U. per hour or 14 H.P., that is, less than one-tenth of the heat introduced.

If the air is humidified by mixing it with steam before it enters the shed more effective cooling may be obtained.* By this method the air may be introduced at 4 or 5 degrees lower temperature and will contain one or two grains of condensed vapour which on re-evaporation in the shed will produce a cooling effect. If steam jets are used the net cooling effect of the ventilating air will be less than the above case by the amount of heat lost from the steam pipes.†

Air Conditioning by Atomised Water.—The most efficient method of cooling a weaving shed would be to maintain an active ventilation and employ cold water to condition the air. Under these conditions a ventilating plant capable of giving one change per hour would with the ordinary difference of temperature between the shed and the outside carry off the entire heat introduced, or the excess of the shed above the outside temperature would be little more than half its present amount.‡

The first method of humidification by cold water brought into use consisted in passing the ventilating air through wet matting, over water or over surfaces kept wet by water spray before admitting it to the shed.

A number of tests of this system were carried out during the course of the Cotton Inquiry both with relatively small experimental apparatus and with ventilating plant of considerably greater power than that usually employed in weaving sheds.

Briefly summarised the results were as follows:—

1°. There is no difficulty in bringing the relative humidity of the incoming air up to 95 per cent., and reducing its temperature to within a degree of the actual wet bulb temperature.

2°. In summer the humidity of an average shed may by this method be maintained at about 60 per cent., or that of a hot shed at about 50 per cent. of saturation.

The simple process of humidifying the incoming air by passing it over wet matting, or through water sprays is therefore satisfactory in all cases where only a low relative humidity is required in the shed. In a hot and dry climate a very considerable cooling effect may be obtained and in fact, the shed can be kept below the outside temperature. In the report on Cotton Weaving sheds full data were given with regard to an Indian Shed ventilated on this system§ and it was shown that during the dry season the temperature in the shed was from 5 degs. to 10 degs. below the outside temperature. But it must be remembered that during the dry season in India, the relative humidity of the outside air averages 20 per cent., and corresponds to a difference between the wet and dry bulbs of 20 or 30 degrees; whereas in the British Isles the average humidity is above 70 per cent. and the average difference between the wet and dry bulbs less than 5 degrees.

No experiments are necessary to make it clear that the saturation of the incoming air by cold water will not provide the humidity required to maintain a hot weaving shed at a high percentage humidity. To take an instance, air saturated at 60° F. contains 5·8 grains of moisture, but air at 80° F., containing 5·8 grains of moisture per cubic foot, has a relative humidity of only 47 per cent. Actually, as some of the moisture introduced is lost, the humidity in the shed would be lower.

As the amount of air introduced increases, the temperature of the shed will fall and its relative humidity rise. With the incoming air saturated at 60° F. the humidity in the shed, neglecting any loss, will be 62 per

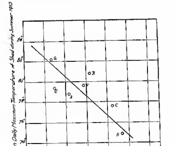

FIG. XXI.

Effect of Floor Space.

A large proportion of the heat is carried away from a weaving shed by conduction through the roof and floor (see Figs. XXII. to XXV. and p.). The heat entering depends on the number of looms, and therefore the larger the floor area per room, the cooler the shed will be.

In the above figure, the average temperatures which the sheds reach in summer are plotted against the surface of the shed, walls, floor and ceiling, per loom. In the most crowded shed the temperature is 82° F., in the one with the largest free floor space the temperature is 75° F. The letter by each point on the diagram indicates the shed to which the point refers.

* *See* Fig. XXIV., page 69.
† *See* Fig. XXII., page 69.
‡ *See* Fig. XXV., page 69.
§ *See* Cotton Report, Cd. 5566, 1911, p. 38, Table 26, and Fig. XVII.

cent. when the shed is at 75° F., 72 per cent. when the shed is at 70° F., and 85 per cent. when the shed is at 65° F., &c. Theoretically, therefore, it would always be possible to cool and humidify a shed satisfactorily by this method. In practice, however, it will be found that where a large relative humidity is necessary in the factory, the amount of ventilating air required is excessive.

The experiments undertaken during the enquiry on cotton weaving sheds* show that where the humidity required is above 70 per cent., some additional method of humidification must be used. During these experiments, attempts were made to supersaturate the air before passing it into the ducts, and for this purpose various forms of water atomizers were placed at the entrance to the ducts. It was found, however, that even the finest spray could not be carried through long ducts. The only practical solution to the problem appears to be either to supersaturate the incoming air by means of steam, or to deliver the atomized water into the free

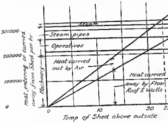

FIG. XXII.

Shed humidified by steam jets.

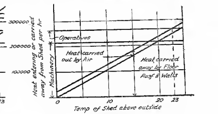

FIG. XXIII.

Shed humidified by passing ventilating air over hot water.

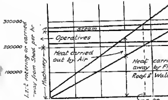

FIG. XXIV.

Shed humidified by passing ventilating air over cold water and steaming at entrance to duct.

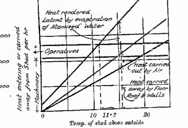

FIG. XXV.

Shed humidified by "atomized" water.

FIGS. XXII. to XXV.

Cooling Effect of various methods of Ventilation and Humidification.

The diagram is drawn for a shed of 250,000 cubic feet capacity containing 250 looms and provided with a ventilating plant capable of giving one change of air per hour. The distance between the successive horizontal lines represents the amount of heat introduced by the various sources (machinery, steam pipes, &c.). The vertical distance between the sloping lines represents the heat carried away by the conductivity of the roof and floor, the specific heat of the air, &c.

The temperature which the shed will attain is fixed by the intersecting of the upper lines of the two systems; for at this point the rates at which heat enters and leaves the shed are equal.

The average flow of heat through roof and floor per square foot of surface per degree temperature difference was determined in a shed under working conditions and found to be 0·3 B.T.U., and this value was used in the calculations.

Fig. XXII. represents the condition of the shed if humidified by steam jets, and Fig. XXIII. if humidified by passing the ventilating air over warm water. In the former case the air enters the shed at atmospheric temperature, but its cooling effect is only equivalent to the additional heat introduced by the steam pipes. For one change of air per hour the effect of the two systems is practically identical, while with a larger ventilating plant the shed using steam jets would be cooler.

Fig. XXIV. represents a shed humidified by passing the ventilating air over cold water or through water sprays and adding steam at the entrance to the duct.

This system is preferable to humidification by steam jets, inasmuch as the heating effect of the steam pipes in the shed is eliminated and the air coming in is slightly cooled; the calculated temperature of the shed is 4·5° F. lower.

In Fig. XXV. the shed is assumed to be humidified by a number of atomizers using cold water. Here the principal cooling effect is due to the evaporation of the water. The shed humidified in this manner is 12° cooler than that in which steam pipes are used.

These results would, of course, not apply to an individual shed on a definite day, but they represent approximately average conditions.

* *See* Cotton Report, Cd. 5566, 1911, p. 38, Tables 23 and 24, Figs. XIV., XV., and XVI.

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air of the shed, or into the ventilating ducts close to the point where the air enters the shed. The first alternative has the obvious disadvantage of decreasing the cooling effect available; the second offers some difficulties where the required humidity is high. Both methods are represented by commercial systems, the first by Matthews and Yates, Parsons', &c., &c.; the second by the Vortex, the Droso-phore, Turbo-humidifier, &c.

Humidification by cold water alone is now being extensively used in the cotton trade, and there can be no doubt that it forms the most effective method of cooling.

Heat Conduction through Roof, Walls, and Floor.—At the present time, most linen sheds are humidified either by passing the incoming air over hot water or by steam jets. In the former case, practically all the heat must be carried off by conduction through the roof, walls, and ceiling of the shed; in the latter case, about two-thirds of the heat is eliminated in this way. The construction of the sheds is similar, and the heat supply per loom does not vary greatly; the temperature will, therefore, depend largely on the cooling surface available.

In Fig. XXI., the average summer temperature in a number of sheds is plotted against the external area per loom.

The difference of temperature between a shed and the outside atmosphere increases from 15 to 24 degrees as the external surface per loom falls from 200 to 100 square feet.

Effect of Various Methods of Humidification.—To summarise the above discussion and illustrate graphically the conclusions, four figures, XXII, XXIII, XXIV, and XXV, showing the heat balance for a shed containing 250 looms, and having a capacity of 250,000 cubic feet, have been prepared.

In all four diagrams, the ventilation is assumed to be equal to one change of air per hour. The outside temperature is taken as 60° F., and the outside humidity 70 per cent., which represents about the average summer conditions during the daytime in Ireland. The rate of heat supply does not vary with the difference of temperature between the shed and the outside atmosphere, while the heat loss increases nearly in proportion to it.* The data from which the diagrams are drawn are taken, as far as possible, from actual observation, but they are of necessity somewhat uncertain, and the object in view is to provide comparative rather than absolute values.

The diagrams show clearly that in all cases the cooling effect of the floor, roof, and walls is, in a weaving shed, of paramount importance, and therefore confirm the conclusion arrived at by a comparison of the maximum temperatures attained in the various sheds under observation, and illustrated in Fig. XXI. Where the incoming air is humidified by hot water, more than 90 per cent. of the heat must pass through the floor, roof, and walls. In sheds humidified by steam jets, or by a duct system using cold water and steam, about 75 per cent. of the heat must escape in this way.

A very considerable increase in ventilation is therefore required to produce an appreciable difference in the shed temperature, and it will generally be found easier to improve the conditions by decreasing the amount of heat introduced, by modifying the method of humidification, or by increasing the amount of free floor space.

Shed Construction.

The question of shed construction was dealt with in a previous report. The conclusions, which have been confirmed by the present investigation, may be summarised as follows:—

1°. The cubical capacity and floor space per loom should be as large as economic conditions will allow. The difference between the inside and outside temperatures for a shed of given size is practically proportional to the number of looms installed.

2°. For the same capacity per loom, a small shed is cooler than a large shed.

3°. A boiler-house or engine-room adjacent to a weaving shed increases the temperature of the shed, and renders it more difficult to obtain uniform hygrometrical conditions. Any hot room should be separated from the shed by an open alley-way.

4°. The design of the roof has an appreciable effect on the temperature of the shed, a concrete roof or a ventilated double roof producing a lower and more uniform temperature.

5°. Owing to the heating effect produced by direct solar radiation the orientation and inclination of the shed lights are of importance. The lights should face north and the angle of the glass should not be less than 60 degrees to the horizontal.

6°. The choice of humidifying plant is of great importance. The use of water atomizers during hot weather is desirable.

7°. The efficiency of the ventilating plant will depend on the shape, size and arrangement of the ducts and on the position and shape of the outlets; full information on this subject will be found in the Second Report of the Departmental Committee on Ventilation of Factories.†

WET SPINNING ROOMS.

General Arrangements.

The general arrangement of Irish spinning rooms varies little from mill to mill. The frames are placed on either side of the main pass, and the stands between the frames extend from window to window. The rove is led through a trough of hot water to the rollers, which are occasionally sulppied with additional water by a drip feed arrangement. For coarse leas, where the pitch of the spindle is greater than 2¾ inches, splash guards are compulsory. The floors are usually thoroughly wet owing to the spray thrown out by the flyers, and gutters are provided at the side of the alleys to carry the water away.

The frames vary in length and the number of spindles per frame is of course greater for the finer leas.

The spinning mill is customarily a four or five storey building with one or two spinning rooms, the other rooms being occupied with preparing and reeling.

Comparison between Spinning Rooms and Weaving Sheds.—The process of flax spinning necessitates the introduction of large quantities of heat to a relatively limited space. Compared with a weaving shed of similar capacity this heat is approximately ten times as great, and were special means of ventilation not employed, unbearable temperatures would be reached in the summer months. Further, the available cooling surface offered by walls, floor and ceiling, is minimised in such spinning rooms as are located between two other hot rooms.

This difference between the thermal conditions associated with spinning and weaving is illustrated in Figs. XXVI. and XXVII., which are drawn to the same scale, and refer respectively to a weaving shed and a spinning room. (It will be observed that Fig. XXVI. is a reproduction on a reduced scale of Fig. XXII.)

While in a weaving shed the cooling effect of walls, floor and ceiling is of primary importance, it will be seen that in a spinning room the amount of ventilation is the main factor which determines the maximum temperature which will be attained.

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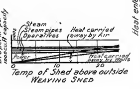
* The heat introduced by the operatives decreases as the temperature of the shed approaches more nearly to the bodily temperature; and the heat introduced by steam pipes falls slightly as the temperature of the shed rises. To avoid complication, these effects have not been shown on the diagrams.

† [Cd. 3552-3], 1907.



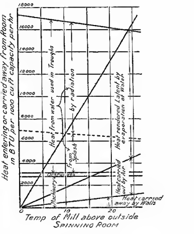


Fig. XXVI. Fig. XXVII.

Comparison of the Conditions in a Weaving Shed and in a Wet Spinning Room.

The diagram XXVI. is drawn for a weaving shed of average size humidified by steam jets and with a ventilating system producing one change of air per hour. Diagram XXVII. represents a spinning room with a ventilating plant producing fourteen changes of air per hour.

Both figures are drawn to the same scale. The heat introduced by each source (machinery, operatives, &c.) is represented by the vertical distance between the sloping lines. The temperature of the rooms will rise until the inflow and outflow of heat are equal

It will be seen that for a given capacity the heat introduced into a spinning mill is more than ten times as great as that introduced into a weaving shed, and for this reason the cooling effect of the walls, floor and ceiling of a spinning room is comparatively very small. The temperature of a spinning mill depends essentially on the quantity of air used for ventilation, which in the example shown carried away 95 °/₀ of the total heat (20 °/₀ by its change of temperature and 75 °/₀ by evaporation).

Fig. XXVII. represents fairly average conditions; of the 16,000 B.T.U. introduced per 1,000 cubic feet capacity per hour all but 1,000 is carried away by the ventilation current, and were the walls entirely impervious to heat the maximum temperature reached would be but little increased. If on the other hand, all ventilation, both natural and artificial, were entirely suppressed, the temperature would at first rise at a rate of 20 or 30 degrees per hour. This rate would of course diminish as the difference between the temperature of the room and the temperature of the troughs increased, and the excess of the room temperature over the outside temperature increased; but under these circumstances the room would become intolerably hot before a balance had been obtained.

It was obviously not possible to obtain direct experimental confirmation of the above, as it would have involved stoppage of the work and risk of heat stroke to some of the workers, but the opportunity was taken after work had ceased on a Saturday to measure the rate of rise of temperature produced by the troughs alone. For the purpose of the experiment steam was left on. During the first hour the temperature rose from 80° F. to 107° F. and after the first few minutes the air was saturated, the wet and dry bulb readings being practically the same. During the afternoon the outside temperature was falling, and four hours after the mill had stopped an equilibrium was attained with the room 47 degrees above the outside temperature.

As, during this experiment there was, of course, no heat introduced by the power supplied to the machinery, or by the hot water sprayed off from the flyers, it is clear that a complete stoppage of the ventilation during normal work would produce still more serious conditions.

In the routine working of a mill a sharp rise of temperature at the end of the day is always noticeable and is very marked in winter, but the rise is soon checked by the cooling of the troughs from which steam has been turned off. When the mill stops during meal hours some windows are usually left open, and air also passes into the room through the doors, and natural ventilation replaces to some extent the effect of the fans.

It is obvious that any reduction in temperature can be effected only

(1) by decreasing the quantity of heat introduced, or

(2) by increasing the outward flow of heat.

A consideration of the various sources of heat and methods of ventilation is therefore essential.

Sources of Heat.

The sources of heat in a spinning room may be enumerated as follows :—

(1) The power used in the spinning frames ,
(2) The heat radiated from the troughs ;
(3) The heat carried by the water spray from the flyers ;
(4) The heat radiated from the steam pipes ;
(5) The bodily heat of the operatives ,

and these will be dealt with successively.

Power.—The approximate power generally used by frames working on various leas is given in Table 16, and the figures are confirmed by a number of readings taken in a room driven from an electric power station.

TABLE 16.

POWER USED BY FRAMES OF VARIOUS PITCHES.

Pitch in Inches	Number of Spindles	Horse Power
2¾	142	3·7
2½	128	3·6
2¼	184	2·0
2	196	2·0
1¾	304	2·6

It may be concluded, therefore, that a frame of average size uses 3¼ H.P., *i.e.*, introduces 160 B.T.U. per minute

Radiation from Troughs.—In connection with the last report a series of measurements of radiation from insulated surfaces was undertaken ; and for the present work, investigations of the heat emitted by troughs of the same size and material as those used in spinning frames have been carried out. The loss from surfaces insulated in accordance with the regulations for steam pipes in cotton mills amounts to about ·009 B.T.U. per square foot per degree per minute. The loss from the ordinary wooden trough is some three times as great, and thus a frame of ordinary length (20 feet) introduces 220 B.T.U. per minute. As will be seen below, it is possible to save nearly two-thirds of this loss by replacing the ordinary wooden tanks by better insulated ones. The increased cost would be more than covered by the saving in steam, and a very appreciable reduction of the total heat introduced would be obtained. Up to the present the experiments have only been tried on a small scale, but the question is of sufficient importance to deserve further investigation.

Water Spray.—During spinning processes a considerable quantity of water is carried over by the rove, and finds its way to the floor or into the gutters which are provided to catch it. The water loses the greater part of its heat before leaving the room. The amount of heat thus introduced will vary over wide limits with the leas spun. For very fine yarns it is comparatively unimportant, but for coarse ones may reach as much as 100 B.T.U. per frame per minute.

Steam Pipes.—The heat from bare steam pipes will be ·05 B.T.U. per square foot per degree per minute, or ·005 B.T.U. for the best efficient covering possible. The coverings at present in use are often of inferior material and in an indifferent state of preservation, and ·01 B.T.U. seems a reasonable estimate for the heat loss. On this figure the heat per frame works out at 14 B.T.U. per minute.

Bodily Heat of Operatives.—The usually accepted data for the bodily heat of the operatives lead to the relatively small figure 20 B.T.U. per frame per minute. It is thus clear that in comparison with the large amounts of heat which the hot water troughs introduce, the much smaller quantities due to the operatives and steam pipes become relatively unimportant, and even the power for the machinery accounts for less than one-third of the total. In a weaving shed on the other hand, the power is the source of two-thirds the total heat, while the operatives and steam pipes together account for the balance.

The above considerations apply to rooms spinning from 30 to 60 lea. For a room where very fine yarn is worked the relative importance of the sources of heat are approximately : Power, 25 ; Radiation, 60 ; Spray, 10; Steam Pipes, 3 ; and Operatives, 2. For a very coarse room : Power, 30 ; Radiation, 45 ; Spray, 20 ; Steam Pipes, 3, Operatives, 2.

Efflux of Heat.

The heat loss may be conveniently divided into three parts :—

(1) The heat passing through the walls, windows, floor and ceiling of the room.
(2) The heat carried away by the outgoing air which is at a higher temperature than the incoming air.
(3) The latent heat of the water removed as vapour in the air current.

The question is discussed fully below and it is sufficient here merely to state that in an average spinning mill the heat lost by conduction is about 6 or 8 per cent. ; that carried away by the air, 20 per cent. ; and that due to the evaporation of the water, 75 per cent. of the total. Although these sub-divisions have no great claim to accuracy, they justify the following general statements, namely,—

(1) That a reduction in the heat entering a room can be effected only by better insulation of the troughs, and (2) that an increase in the heat carried away can be effectively produced only by more efficient ventilation ; for the total heat introduced is so great that the cooling effect of walls or floor becomes comparatively inappreciable.

Present Conditions.

Average Temperature and Humidity.—The temperature records received at the Home Office from all the Irish mills were analysed, and Table 17 gives the average wet and dry bulb temperatures for the month of August for 140 spinning rooms. The average temperatures during this month are 80·3° F. dry and 75° F. wet.

TABLE 17.

IRISH WET SPINNING ROOMS.

AVERAGE WET AND DRY BULB TEMPERATURES DURING AUGUST, 1913, FROM HOME OFFICE RECORDS.

Room	Readings of Thermometers in °F. Between 10 a.m. and 11 a.m.			Between 3 p.m. and 4 p.m.		
	Dry Bulb.	Wet Bulb.	Difference.	Dry Bulb.	Wet Bulb.	Difference.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A.—*Rooms investigated*						
L	81	76	5	81	75	6
M	80	76	4	83	76	7
N	80	76	4	82	78	4
O	78	70	8	80	72	8
P	81	72	9	82	72	10
R	84	79	5	85	80	5
S	83	78	5	84	79	5
T	84	79	5	84	78	6
U	82	77	5	83	79	4
B.—*Other Rooms.*						
No.						
101	82	76	6	83	76	7
102	81	77	4	83	78	5
103	81	78	5	81	76	5
104	81	77	4	81	77	4
105	80	77	3	80	77	3
106	80	77	3	81	78	3
107	78	74	4	78	74	4
108	79	74	5	80	73	7
109	81	76	5	81	76	5
110	78	73	5	79	74	5
111	76	70	6	76	70	6
112	75	69	6	75	69	6
113	79	75	4	78	74	4
114	81	76	5	82	76	6
115	80	76	4	81	77	4
116	74	68	6	74	68	6
117	74	68	6	75	68	7
118	76	70	6	76	70	6
119	83	78	5	83	78	5
120	80	75	5	80	75	5
121	83	77	6	83	77	6
122	82	77	5	83	78	5
123	80	72	8	81	72	9
124	78	70	8	79	70	9
125	80	70	10	80	71	9
126	80	72	8	81	72	8
127	81	72	9	81	71	10
128	74	68	6	75	88	7
129	74	69	5	75	69	6
130	74	71	3	75	72	3
131	78	75	3	78	75	3
132	77	73	4	78	73	5
133	80	75	5	81	76	5
134	80	75	5	80	74	6
135	80	75	5	80	74	6
136	79	74	5	78	73	5
137	77	72	5	77	72	5
138	77	73	4	78	73	5
139	83	77	6	83	77	6
140	85	78	7	85	78	7
141	80	74	6	80	74	6
142	79	74	5	79	73	6
143	80	71	9	80	71	9
144	76	72	4	76	72	4
145	80	78	4	81	76	5
146	77	73	4	78	74	4
147	79	74	5	79	74	5
148	79	74	5	80	75	5
149	79	75	4	80	75	5
150	80	75	5	81	76	5
151	80	72	8	78	72	6
152	79	74	5	79	75	5
153	80	75	5	80	75	5
154	79	72	7	81	72	9
155	79	74	5	79	75	4
156	79	75	4	79	75	4
157	80	75	5	80	74	6
158	79	73	6	80	73	7
159	79	73	6	79	73	6
160	79	73	6	78	72	6
161	81	77	4	82	77	5
162	82	78	4	83	79	4
163	82	77	5	83	78	5
164	83	74	9	83	74	9
165	83	76	7	84	75	9
166	79	73	6	80	73	7
167	82	77	5	83	77	6
168	74	70	4	74	70	4
169	72	67	5	73	68	5
170	80	74	6	82	75	7
171	81	76	5	83	77	6
172	82	77	5	83	76	5
173	80	73	7	80	73	7
174	83	77	6	83	77	6
175	82	76	6	82	76	6
176	80	74	6	79	74	5
177	80	75	5	81	76	5
178	74	71	3	74	71	3
179	85	80	5	86	80	6
180	83	78	5	83	78	5
181	85	80	5	84	79	5
182	85	80	5	85	79	6
183	81	76	5	81	76	5
184	83	78	5	83	77	6
185	86	82	4	87	82	5
186	83	79	4	85	80	5
187	82	78	4	83	79	4
188	78	74	4	79	75	4
189	76	71	5	77	73	4
190	83	79	4	83	79	4
191	82	77	5	82	76	6
192	80	76	4	80	76	4
193	79	76	3	79	76	3
194	78	76	2	79	76	3
195	80	76	4	80	76	4
196	82	78	4	81	77	4
197	75	68	7	75	89	6
198	76	70	6	77	72	5
199	77	71	6	78	73	5
200	80	71	9	81	72	9
201	81	75	6	81	75	6
202	78	75	3	78	75	3
203	83	77	6	83	77	6
204	82	75	7	82	75	7
205	83	77	6	84	78	6
206	82	77	5	83	77	6
207	82	75	7	85	79	6
208	80	74	6	80	75	5
209	82	73	9	83	74	9
210	80	73	7	80	74	6
211	79	75	4	80	76	4
212	81	77	4	83	77	6
213	82	80	2	83	81	2
214	83	79	4	84	80	4
215	75	70	5	78	70	6
216	78	74	4	79	75	4
217	80	76	4	81	76	5

u 23030 K

TABLE 17—*continued.*

Room.	Readings of Thermometers in ° F. Between 10 a.m. and 11 a.m. Dry Bulb.	Wet Bulb.	Difference.	Between 3 p.m. and 4 p.m. Dry Bulb.	Wet Bulb.	Difference.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
No.						
218	78	75	3	78	75	3
219	78	75	3	78	76	2
220	82	77	5	82	77	5
221	79	75	4	79	76	3
222	84	82	2	85	82	3
223	89	82	7	90	81	9
224	81	76	5	82	78	4
225	77	73	4	77	73	4
No.						
226	79	74	5	79	74	5
227	79	76	3	80	76	4
228	79	76	3	80	76	4
229	80	76	4	82	78	4
230	81	77	4	82	77	5
231	83	80	3	83	80	3
232	81	78	3	81	78	3
Average	80·0	74·9	5·1	80·6	75·2	5·4

The average difference between the wet and dry bulb is therefore 5·3 degrees. In 14 rooms the average difference was 8 degrees or more, but this, however, is probably an under-estimate, as several mills which always maintain a comparatively low humidity do not send temperature records to the Home Office. In 14 other mills the average temperature difference was 3 degrees or less. The highest average temperature was 89·5° F. (in Room No. 223), and the coolest room was No. 169, with an average dry bulb temperature of 72·5° F.

In a similar manner Table 18 gives the average dry and wet bulb temperatures for these Irish mills during January, the month of lowest outside mean temperature.

TABLE 18.

IRISH WET SPINNING ROOMS.

AVERAGE WET AND DRY BULB TEMPERATURES DURING JANUARY 1913, FROM HOME OFFICE RECORDS

Room.	Readings of Thermometers in ° F. Between 10 a.m. and 11 a.m. Dry Bulb.	Wet Bulb.	Difference.	Between 3 p.m. and 4 p.m. Dry Bulb.	Wet Bulb.	Difference.
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	A.—*Rooms Investigated*					
"L"	81	79	2	31	79	2
"M"	80	76	4	81	77	4
"N"	81	78	3	82	78	4
"O"	73	68	5	73	67	6
"P"	78	72	6	78	72	6
"R"	78	73	5	78	73	5
"S"	82	78	4	82	78	4
"T"	83	79	4	83	79	4
"U"	81	77	4	81	77	4
	B.—*Other Rooms.*					
No.						
101	79	74	5	79	75	4
102	78	74	4	77	73	4
103	75	72	3	75	72	3
104	81	77	4	81	77	4
105	79	76	3	79	76	3
106	79	76	3	79	76	3
107	78	74	4	79	75	4
108	74	71	3	74	71	3
109	81	77	4	81	77	4
110	78	75	3	77	74	3
111	76	71	5	77	72	5
112	76	71	5	77	72	5
113	77	72	5	78	73	5
114	79	75	4	80	75	5
115	76	72	4	76	72	4
116	71	66	5	71	66	5
117	71	66	5	71	66	5
118	69	66	3	69	65	4
119	80	77	3	81	77	4
120	79	74	5	79	74	5
121	77	71	6	76	71	5
No.						
122	80	75	5	79	73	6
123	75	68	7	76	69	7
124	—	—	—	—	—	—
125	78	72	0	78	72	6
126	78	72	6	77	72	5
127	79	70	9	79	71	8
128	74	70	4	75	70	5
129	74	69	5	74	69	5
130	78	74	4	79	75	4
131	77	74	3	78	75	3
132	80	74	6	80	75	5
133	80	75	5	80	75	5
134	80	74	6	80	74	6
135	81	75	6	80	74	6
136	78	72	6	79	73	6
137	76	70	6	77	71	6
138	75	71	4	76	72	4
139	32	77	5	82	77	5
140	82	77	5	83	78	5
141	78	73	5	78	73	5
142	—	—	—	—	—	—
143	78	71	7	77	70	7
144	76	72	4	75	71	4
145	78	75	3	79	75	4
146	74	71	3	74	71	3
147	78	74	4	79	74	5
148	79	75	4	79	75	4
149	77	73	4	77	73	4
150	78	74	4	79	74	4
151	77	71	6	78	71	7
152	78	73	5	78	74	4
153	79	74	5	70	74	5
154	76	70	6	76	70	6
155	80	75	5	79	75	4
156	78	73	5	78	73	5
157	77	73	4	77	74	3
158	78	73	5	79	73	6

TABLE 18—*continued.*

Room.	Readings of Thermometers in ° F. Between 10 a.m. and 11 a.m. Dry Bulb.	Wet Bulb.	Difference.	Between 3 p.m. and 4 p.m. Dry Bulb.	Wet Bulb.	Difference.	Room.	Readings of Thermometers in ° F. Between 10 a.m. and 11 a.m. Dry Bulb.	Wet Bulb.	Difference.	Between 3 p.m. and 4 p.m. Dry Bulb.	Wet Bulb.	Difference.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(1)	(2)	(3)	(4)	(5)	(6)	(7)
No.							No.						
159 -	75	71	4	77	73	4	197 -	69	63	6	71	65	6
160 -	78	73	5	79	74	5	198 -	73	68	5	74	70	4
161 -	82	78	4	82	78	4	199 -	71	66	5	74	69	5
162 -	80	77	3	80	77	3	200 -	75	70	5	75	71	4
163 -	81	77	4	82	77	5	201 -	74	69	5	74	70	4
164 -	82	74	8	82	74	8	202 -	72	70	2	73	71	2
165 -	80	73	7	79	72	7	203 -	79	75	4	80	75	5
166 -	79	75	4	79	74	5	204 -	79	74	5	79	75	4
167 -	83	79	4	83	80	3	205 -	78	74	4	79	75	4
168 -	73	69	4	73	69	4	206 -	83	79	4	85	80	5
169 -	71	66	5	72	67	5	207 -	78	74	4	80	76	4
170 -	76	72	4	77	73	4	208 -	76	71	5	77	72	5
171 -	80	75	5	80	75	5	209 -	76	68	8	76	70	6
172 -	78	74	4	78	74	4	210 -	76	70	6	76	71	5
173 -	—	—	—	—	—	—	211 -	79	76	3	80	76	4
174 -	76	72	4	76	72	4	212 -	71	68	3	71	68	3
175 -	81	76	5	81	76	5	213 -	77	75	2	76	74	2
176 -	75	70	5	75	70	5	214 -	—	—	—	—	—	—
177 -	76	72	4	78	73	5	215 -	72	69	3	73	69	4
178 -	70	68	2	70	68	2	216 -	75	72	3	75	72	3
179 -	85	80	5	86	81	5	217 -	78	75	3	79	76	3
180 -	82	78	4	82	78	4	218 -	78	75	3	78	75	3
181 -	82	78	4	83	80	3	219 -	77	74	3	78	75	3
182 -	80	77	3	79	76	3	220 -	81	78	3	83	79	4
183 -	77	74	3	77	74	3	221 -	—	—	—	—	—	—
184 -	80	76	4	79	75	4	222 -	82	80	2	82	80	2
185 -	84	80	4	84	80	4	223 -	84	81	3	85	81	4
186 -	82	79	3	83	80	3	224 -	80	76	4	80	76	4
187 -	83	79	4	83	79	4	225 -	82	79	3	83	79	4
188 -	75	71	4	76	73	3	226 -	77	73	4	76	73	3
189 -	76	72	4	76	73	4	227 -	76	73	3	76	73	3
190 -	76	74	2	77	75	2	228 -	—	—	—	—	—	—
191 -	80	77	3	80	77	3	229 -	81	77	4	81	76	5
192 -	79	76	3	79	76	3	230 -	80	76	4	80	76	4
193 -	78	76	2	79	77	2	231 -	81	78	3	81	78	3
194 -	79	77	2	79	77	2	232 -	80	78	2	81	78	3
195 -	79	75	4	79	75	4							
196 -	82	78	4	82	79	3	Average	78·0	73·7	4·3	78·3	74·0	4·3

Notwithstanding the fact that the difference of mean outside temperature from August to January was some 18 degrees it will be seen from a comparison of Tables 17 and 18 that the inside temperature varies less than 3 degrees from summer to winter, the mean dry bulb temperatures being respectively 80·3° F. and 78·2° F. The excess of dry over wet bulb temperature is rather less in winter than in summer, and the average winter wet bulb temperature in the spinning mills (73·8° F.) is only 1·2 degrees below that in August (75·0° F.).

In January, out of 135 rooms 29 showed an average difference of 3 degrees or less between wet and dry bulb temperatures; while in two rooms the difference was at least 8 degrees.

The highest average dry bulb temperature was 85½° F. in Room No. 179, the lowest, 69° F. in Room No. 118.

In Table 19 the number of rooms at various average temperatures is given, and it will be seen that in August three-quarters of the rooms are between 78° F. and 84° F., in January between 76° F. and 82° F.

During the month of August one room exceeded 90° F. on six days, and three mills exceeded it on at least one day.

TABLE 19.

NUMBER OF WET SPINNING ROOMS WHICH WORK AT GIVEN MEAN TEMPERATURES

Month.	Mean Temperatures of Spinning Rooms in ° F. 70°–72°	72°–74°	74°–76°	76°–78°	78°–80°	80°–82°	82°–84°	84°–86°	86°–88°	88°–90°
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
August - -	0	1	10	11	33	43	33	8	1	1
January - -	6	6	18	29	39	22	15	4	0	0

Note.—In August 43 out of 141 mills, or 30 per cent. of the mills, work at mean temperatures, between 80° F. and 82° F., while 109, or 77 per cent. average from 78° F. to 84° F. In January 39 out of 135, or 29 per cent. of the mills, work at mean temperatures, between 78° F. and 80° F., while 90, or 67 per cent., average from 76° F. to 82° F.

Recording instruments were maintained during the summer months in seven of these spinning rooms and in one for an entire year.

TABLE 20.

DETAILS OF

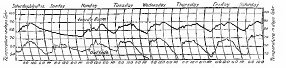
Room.	No. of Frames.	No of Operatives.	Capacity (Cub Ft.). Total.	Per Standard Frame of 20 Ft.	Per Operative	Aspect of Room Windows.	Height of Room (Ft.).	Storey.	Length (Ft.).	Breadth (Ft.).	Leas Spun
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
							Ft. Ins.				
"L"	36	92	87,800	2,440	955	E. & W.	11 6	4	166	46	30s–75s
"M"	36	87	87,000	2,420	1,000	E. & W.	11 6	3	166	45	60s–140s
"N"	39	150	135,000	3,460	900	E. & W.	12 7	3	224	40 (mean)	16s–40s
"O"	44	122	101,500	2,540	832	N. & S.	12 6	2	185	42 (approx.)	20s–140s
"P"	10½	33	28,900	2,830	876	N.,S. & W.	13 4	5	66	33	150s–230s
"Q"	42 (25 ft. 6 ins. long).	103	157,000	2,910	1,520	E. & W.	12 9	4	192	64	40s–150s
"R"	26 (29 ft. 6 ins. long).	110	123,000	3,240	1,120	E. & W.	13 6	3	136	70	16s–32s
"S"	22 (18 ft. long).	59	44,700	2,240	760	N. & S.	10 0	3	110	41	25s–50s
"T"	26 (18 ft. long).	62	38,200	2,900	1,100	N. & S.	12 6	4	130	41	70s–140s
"U"	19	57	59,800	3,150	1,050	E. & W.	13 0	4	90	51	100s–190s
"Z"	27	44	53,500	1,980	1,220	N. & S	11 6	2	124	46	40s–65s

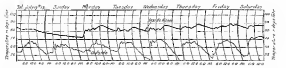
TABLE 20

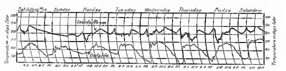
Spinning Rooms

Ventilation.	Approximate output of Fans (Cub. Ft. per Hour)	Changes per Hour by Fans (in Cub. Ft. per Linear Ft. of Frame).	Approximate Length of Steam Pipes.	Width of Main Pass.	Width of Stands Spindle to Spindle.	Room above.	Room below.	Mean Temperature during Summer 1913
(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
				Ft. In.	Ft. In.			
Three 15 in. centrifugal exhaust fans drawing from centre of room	—	—	351 ft. of 1½ in. 197 ,, 2 in. 120 ,, ¼ ,,	3 9	5 2	Reeling	Spinning	80·3
Two 24 in. exhaust propeller fans.	—	—	349 ,, 1½ in. 197 ,, 2 in. 321 ,, ¾ ,,	3 9	5 2	Spinning	Preparing	79·9
Three 24 in. exhaust propeller fans	846,000	1,086	408 ,, 3 ,,	5 0	5 8	Spinning	Preparing	81·9
One 15 in. centrifugal. Five 25 in. propeller. One 30 in. propeller.	—	—	Covered. 23 ft. of 4 in. 30 ,, 3 ,, 66 ,, 2½ in. 335 ,, 2 in. 70 ,, 1¼ in. 30 ft. of 1¼ in. 180 ,, 1 in. 60 ,, ¾ ,, 304 ,, ⅝ ,, 178 ,, ½ ,,	4 9	4 8	Spinning	Spinning	79·9
One 17 in. centrifugal plenum Two 30 in. exhaust propeller. Plenum to top of creels. Exhaust from bottom of creel.	—	—	165 ,, 1¼ ,, (covered) 84 ft. of ¾ in. 57 ,, ½ ,, 12 ,, 1 ,,	2 11	4 4	Winding	Spinning	82·2
One 48 in. exhaust propeller.	1,080,000	1,010	426 ,, 3 ,, (covered) 353 ft. of 1 in. 200 ,, ¾ ,, 24 ,, ½ ,,	13 4	5 6	Roof	Preparing	—
Four 20 in. exhaust draw through ducts from ceiling above centre of frames.	528,000	690	284 ,, 4 ,, 247 ,, 1 ,,	7 0	5 10	Reeling	Preparing	82·7
Two 34 in. propeller exhaust.	1,140,000 or when throttled 762,000	2,880 1,930	240 ,, 1½ ,, 69 ,, ¾ ,,	2 3	5 0	Spinning	Preparing	87·0
One 30 in. propeller exhaust. One propeller plenum.	—	—	280 ,, 1½ in. 81 ,, ¾ in.	3 5	5 1	Spinning	Spinning	—
One 24 in. propeller exhaust.	180,000 (?)	474 (?)	241 ,, 1½ in. 66 ,, ¾ in.	4 6	6 2	Reeling	Reeling	—
Two 22 in. propeller exhaust.	—	—	None used for troughs.	6 0	5 2	Reeling	Preparing	70·4

The records obtained differ very materially from those obtained in weaving sheds. The regular rise during working hours and sharp drop marking meal hours, which were found in the latter case, are absent, the temperature variation throughout the day being quite erratic. Three records typical of the conditions prevailing during a hot week in summer are reproduced in Figs. XXVIII., XXIX., XXX.







Figs. XXVIII., XXIX., XXX.

In Figs XXVIII. and XXIX., the upper curves are reproductions of continuous temperature records in two typical spinning rooms, while the upper curve of Fig. XXX. represents the temperature of a room in the exempted mill referred to on p. 91. The lower curves in these figures give the outside temperatures. The continuous rise of temperature during working hours, and sharp fall at meal times, which were typical of the weaving shed records (see Figs. I., II, III., &c.) do not exist in the spinning mills. The temperature in the spinning room varies quite irregularly within relatively narrow limits, and rises but little with the outside temperature.

In all mills there is a rapid rise of temperature when the steam is turned on in the morning; in some mills there is a sharp drop when the work commences and the fans are started (see Fig. XXX.). When the machinery stops at the end of the working day, the temperature of the spinning mills rises and falls again slowly some hours later.

In summer the average spinning room is about 30 degrees above the outside temperature in the early morning, and 15 or 20 degrees above the outside temperature at noon. The average temperature in the mill exceeds the average outside temperature by 25 degrees.

In most mills the steam is turned on two or three hours before work starts, and a rapid rise of temperature generally results. On the commencement of work, however, ventilation comes into operation, and frequently brings about a sudden cooling, which is more marked in some mills than others.

Temperature charts for a cold period in winter are reproduced for Room "R" in Fig. XXXI.

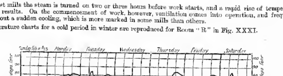


Fig. XXXI.

Fig. XXXI. is a reproduction of a temperature record taken in a spinning room during a cold week in winter; except for the somewhat lower average temperature and for the large rise of temperature on the Monday morning, the record does not differ greatly from Fig. XXIX. taken in the same mill in the summer.

There is a very sharp rise at the beginning of the day, but after the first hour or two the variations are quite irregular. In summer, however, this room tends to a gradual, though very uneven, rise throughout the working day. (See Fig. XXIX.)

The mean temperatures during working hours, as computed from the daily records in the spinning mills in which recording instruments were used, are given in Table 21.

TABLE 21.

MEAN TEMPERATURE FROM RECORDING INSTRUMENTS IN WET SPINNING ROOMS DURING WORKING HOURS.

Room.	June.			July.			August.			Summer.		
	Inside Mean Temperature.	Outside Mean Temperature.	Difference.	Inside Mean Temperature.	Outside Mean Temperature.	Difference.	Inside Mean Temperature.	Outside Mean Temperature.	Difference.	Inside Mean Temperature.	Outside Mean Temperature.	Difference.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	° F.	° F.		° F.	° F.		° F.	° F.		° F.	° F.	
"L" -	79·1	54·2	24·9	81·0	56·4	24·6	*80·7	56·4	24·3	80·3	55·7	24·6
"M" -	80·0	54·2	25·8	79·8	56·4	23·4	—	—	—	79·9	55·3	24·6
"N" -	80·6	55·3	25·3	83·2	56·8	26·4	82·0	57·8	24·2	81·9	56·6	25·3
"O" -	78·4	55·3	23·1	79·8	56·8	23·0	*81·4	56·6	24·8	79·9	56·2	23·7
"P" -	—	—	—	—	—	—	*82·2	59·1	23·1	82·2	59·1	23·1
"R" -	81·1	54·8	26·3	83·3	56·8	26·5	*83·8	57·4	26·4	82·7	56·4	26·3
"S" -	—	—	—	—	—	—	*87·0	59·0	28·0	87·0	59·0	28·0
Average -	79·8	54·8	25·0	81·4	56·6	24·8	82·8	57·7	25·1	82·0	56·9	25·1

* For part of the month only.

It will be seen that in the summer months, with an outside temperature of 57° F., the mills averaged 82° F., or 25 degrees above the outside temperature.

The hottest room was 28 degrees in excess of the outside temperature, the coolest 23 degrees.

In general, the temperature of the spinning rooms varied irregularly during the day from some 3 degrees above to 3 degrees below the mean value, although occasionally wider oscillations were found. The highest temperature recorded was 92° F. in Room "S." and temperatures above 85° F. were frequently recorded in all the mills. In Table 22 the maximum and minimum temperatures are given for a single month.

TABLE 22.

MAXIMUM AND MINIMUM TEMPERATURES IN IRISH SPINNING MILLS, JULY 1913.

—	Temperature in ° F.									
	Room "L."		Room "M."		Room "N."		Room "O."		Room "R."	
	Maximum Temperature.	Minimum Temperature.	Maximum Temperature.	Minimum Temperature.	Maximum Temperature.	Minimum Temperature.	Maximum Temperature.	Minimum Temperature.	Maximum Temperature.	Minimum Temperature.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
July 1 - -	83·5	77	83·5	74·5	89	80	86	79	85	81
" 2 - -	84	79	83·5	76	88	84	85	75	83	79
" 3 - -	82	76·5	83·5	78·5	88	78	84	77·5	84	80·5
" 4 - -	81	76	79·5	74·5	85	80·5	77	70·5	84	77
" 7 - -	80	75·5	82	73·5	85·5	76	80·5	71	—	—
" 8 - -	81·5	73	84	75	86·5	80·5	83	79·5	85·5	82
" 9 - -	83	74	85	73	87	82	84·5	77	86·5	82·5
" 10 - -	81·5	73	84	78·5	84·5	78	82·5	73	86	81
" 11 - -	—	—	—	—	87·5	78	83	74	87·5	81
" 14 - -	—	—	—	—	—	—	—	—	87	83
" 15 - -	—	—	—	—	—	—	80·5	74·5	87	85
" 16 - -	80	75·5	81·5	74	80·5	67·5	81·5	70·5	85·5	78
" 17 - -	82·5	76	83	77	82	74·5	82·5	70	86	81
" 18 - -	81·5	76	82·5	79	85	78	85	77·5	82	74
" 21 - -	82	77	84	80	86	78	83·5	68·5	86·5	78
" 22 - -	80·5	76	80	71	88	83	81	77	84·5	80·5
" 23 - -	83·5	75·5	82	76	89	83	85·5	76·5	86	81
" 24 - -	81·5	74·5	82	74	87	82	82	72	86	83·5
" 25 - -	84	77	80	72	88·5	83	84	69	87	83·5
" 28 - -	84	79	—	—	88	83	83·5	78	—	—
" 29 - -	87·5	76·5	87·5	75	88·5	83·5	87	81	—	—
" 30 - -	86·5	77·5	84·5	75·5	88	81·5	87	80	—	—
" 31 - -	86	76·5	85·5	74·5	87	82	87	78	—	—

For purposes of comparison complete tables were prepared, but to save space are not reproduced.

It has already been pointed out from an examination of Tables 17 and 18 that the range of temperature in a spinning mill averages less than 3 degrees from January to August. In weaving sheds the seasonal variation of temperature was found to be much greater, amounting to about one half the range of outside temperature.

It is probable that this difference may be accounted for by a natural tendency to open more windows in the spinning mills in hot weather, and thus by the increased ventilation to check in some measure the temperature rise which would otherwise occur. Fig. XXXII. gives a graphical representation of the relation between inside and outside temperature for an average spinning room (No. 150). It will be noticed that the rate of increase of inside with outside temperature is very slow, the extreme difference inside being only 3 degrees from summer (with an inside temperature of 80° F.) to winter (with an inside temperature of 77° F.), while the outside temperature varies over 18 degrees.

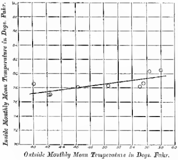


FIG. XXXII.

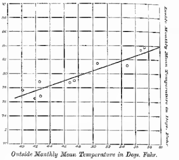


FIG. XXXIII.

FIGS. XXXII. AND XXXIII.

Fig. XXXII. shows the monthly variation of temperature in an average spinning room. It will be noticed that the range of mean inside temperature from summer to winter is only some two or three degrees, while the mean monthly outside temperature varies from 40° F. to 58° F. or 18 degrees.

Fig. XXXIII. is for a hot mill where the variation of temperature with season is exceptionally large.

In Fig XXXIII. a similar curve is reproduced for Room "R," the values here being obtained from the continuous records taken in this mill over an entire year. This mill shows differences of temperature from summer to winter which amount to 7 degrees, a much larger variation than average, and corresponding to about 1 degree rise inside the room for 3 degrees rise in the outside temperature.

In Table 23 the mean monthly temperatures for Room "R" are given, and are compared with the corresponding outside temperatures.

TABLE 23.

MEAN MONTHLY TEMPERATURE IN A WET SPINNING ROOM. ("R.")

Date.	Inside Mean Temperature.	Outside Mean Temperature.	Difference.	Date.	Inside Mean Temperature	Outside Mean Temperature.	Difference.
1912.				1913.			
October	79·0	47·4	31·6	March	76·4	41·9	34·5
November	76·8	42·6	34·2	April	78·7	46·8	31·9
December	—	—	—	May	81·4	50·6	30·8
1913				June	81·1	54·8	26·3
January	77·6	40·1	37·5	July	83·3	56·8	26·5
February	78·8	42·5	36·3	August	83·8	57·4	26·4

The difference in summer is about 26 degrees, in winter about 36 degrees.

Effect of Sunshine.—It has already been observed that in a spinning room about ten times as much heat is introduced as in a weaving shed of similar dimensions. Solar radiation, therefore, which was found to have a considerable influence upon the temperature rise of weaving sheds will here be relatively smaller.

Analysis shows that the effect is, as would be anticipated from differences in orientation, absence or presence of window-blinds, &c., rather variable. The maximum rise shown due to 10 hours' sunshine was 2·5 degrees for Room "N." and the average nearly 2 degrees, whilst for some mills the influence of solar radiation is negligible.

TABLE 24.

EFFECT OF SUNSHINE ON THE TEMPERATURE OF SPINNING ROOMS.

—	Outside Mean Temperature, 50° F. to 55° F.			Outside Mean Temperature, 55° F. to 60° F.		
	Hours of Sunshine.	Outside Mean Temperature	Inside Mean Temperature	Hours of Sunshine.	Outside Mean Temperature.	Inside Mean Temperature
Room "L" - - -	9·1 0·2	53·3 53·3	78·5 77·8	11·4 0·4	56·9 57·7	80·4 80·4
Difference	8·9	0·0	0·7	11·0	− 0·8	0·0
Room "N" - - -	10·1 0·1	53·8 54·3	82·4 80·0	11·4 0·4	57·6 57·8	83·9 80·9
Difference	10·0	− 0·5	2·4	11·0	− 0·2	3·0
Room (2) "O" - -	10·1 0·1	53·7 54·3	79·2 78·2	11·4 0·4	57·6 57·9	82·4 79·9
Difference	10·0	− 0·6	1·0	11·0	− 0·3	2·5
Room "R" - - -	9·0 0·1	53·9 53·8	82·3 80·3	11·9 0·3	57·6 57·7	82·9 82·6
Difference	8·9	0·1	2·0	11·6	− 0·1	0·3

Note.—Ten hours sunshine on an average produces nearly 2 degrees rise of temperature in a spinning room, but some rooms are practically unaffected by sunshine

Exempted Rooms.—A few rooms which continuously maintain a difference of more than 4 degrees between the wet and dry bulb temperatures are exempted from sending records to the Home Office. Averages in two rooms where this exemption has been obtained are shown in Table 25. Ten daily wet and dry bulb readings were taken during the entire year and carefully analysed. Table 25, gives the averages during the summer and winter, and Table 26 the actual readings in one room for the month of August. In such the difference is much larger than in an average mill and varies from 6 or 8 degrees in winter to 8 or 10 degrees in summer.

TABLE 25.

COMPARISON OF MEAN DRY AND WET BULB TEMPERATURES IN EXEMPTED AND ORDINARY SPINNING ROOMS.

Room	Summer.				Winter.			
	Month.	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference.	Month.	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Exempted Rooms:		°	°	°		°	°	°
"P" - -	June - July - August -	80·2 81·1 81·6	72·5 72·3 72·0	7·7 8·8 9·6	January February March -	77·6 78·6 74·2	70·8 70·7 67·1	6·8 7·9 7·1
	Mean -	81·0	72·3	8·7	Mean -	76·8	69·5	7·3
"Q" - -	June - July - August -	76·5 77·0 77·2	69·4 69·9 69·6	7·1 7·1 7·6	January February March -	74·2 74·7 75·4	67·6 68·2 68·5	6·6 6·5 6·9
	Mean -	76·9	69·6	7·3	Mean -	74·8	68·1	6·7
Average for Exempted Rooms	—	79·0	71·0	8·0	—	75·8	68·8	7·0
B. Ordinary Rooms:		°	°	°		°	°	°
"109" - -	June - July - August -	81·4 81·2 81·2	77·2 76·8 76·3	4·2 4·4 4·9	January February March -	81·3 80·6 79·9	76·6 76·7 75·8	4·7 3·9 4·1
	Mean -	81·3	76·8	4·5	Mean -	80·6	76·4	4·2
"103" - -	June - July - August -	80·0 80·4 81·0	76·2 75·7 76·1	3·8 4·7 4·9	January February March -	75·3 76·0 73·6	72·0 72·5 69·8	3·3 3·5 3·8
	Mean -	80·5	76·0	4·5	Mean -	75·0	71·4	3·5
Average for Ordinary Rooms	—	80·9	76·4	4·5	—	77·8	73·0	3·9

TABLE 26.

WET AND DRY BULB TEMPERATURE READINGS IN AN EXEMPTED SPINNING ROOM.

Room "P."

	3 a.m.			6.30 a.m.			7 a.m.			11 a.m.			4 p.m.		
Date	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference.	Dry Bulb Temperature.	Wet Bulb Temperature	Difference	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
North End. August.															
1	80	74	6	84	76	8	84	75	9	83	75	8	83	73	10
2	81	74	7	82	72	10	82	72	10	82	71	11	—	—	—
4	—	—	—	82	73	9	82	73	9	81	70	11	83	70	13
5	79	73	6	80	68	12	80	68	12	79	70	9	81	71	10
6	80	74	6	81	72	9	81	72	9	80	70	10	80	70	10
7	80	74	6	82	75	7	82	75	7	79	67	12	82	70	12
8	79	73	6	82	78	9	82	73	9	81	71	10	81	73	8
9	80	74	6	82	70	12	82	70	12	81	70	11	—	—	—
11	—	—	—	79	70	9	79	70	9	80	71	9	79	67	12
12	79	72	7	78	70	8	78	69	9	80	70	10	81	70	11
13	78	71	7	80	74	6	80	74	6	80	71	9	81	70	11
14	79	72	7	81	74	7	81	74	7	81	74	7	81	74	7
15	82	74	8	85	78	7	85	78	7	81	74	7	80	73	7
18	84	77	7	83	74	9	83	74	9	—	—	—	—	—	—
18	—	—	—	79	70	9	79	70	9	79	70	9	82	71	11
19	80	73	7	82	74	8	82	74	8	81	72	9	83	72	11
20	81	74	7	82	74	8	82	74	8	80	69	11	80	67	13
21	80	73	7	82	73	9	82	73	9	81	73	8	82	71	11
22	79	72	7	80	72	8	80	72	8	79	70	9	82	71	11
23	79	72	7	80	70	10	80	70	10	78	68	10	—	—	—
25	—	—	—	76	69	7	79	69	10	79	68	11	83	74	9
26	81	74	7	81	73	8	81	73	8	83	74	9	85	75	10
27	80	74	6	82	74	8	82	74	8	82	73	9	85	73	12
28	80	74	6	81	71	10	81	71	10	83	74	9	85	76	9
29	82	75	7	84	74	10	84	74	10	84	75	9	85	75	10
30	82	76	6	84	76	8	84	78	8	81	71	10	—	—	—
Average.	80·2	73·6	6·6	81·3	72·7	8·8	81·3	72·7	8·6	80·7	71·2	9·5	82·1	71·7	10·4
South End. August.															
1	80	74	6	84	75	9	84	75	9	83	76	7	—	—	—
2	80	74	6	82	74	8	82	74	8	84	72	12	—	—	—
4	—	—	—	82	72	10	82	72	10	81	69	12	81	70	11
5	79	73	6	82	70	12	82	70	12	82	71	11	83	72	11
6	80	73	7	82	73	9	82	73	9	81	69	12	81	70	11
7	80	73	7	82	74	8	82	74	8	79	67	12	82	69	13
8	79	73	8	81	73	8	81	73	8	82	72	10	82	72	10
9	80	74	6	83	71	12	83	71	12	83	72	11	—	—	—
11	—	—	—	80	71	9	80	71	9	82	72	10	81	68	13
12	79	73	8	79	70	9	79	70	9	82	71	11	83	71	12
13	78	72	6	81	74	7	81	74	7	83	73	10	84	72	12
14	79	73	8	82	74	8	82	74	8	82	75	7	83	75	8
15	80	73	7	85	77	8	85	77	8	82	74	8	82	74	8
16	83	77	6	84	74	10	84	74	10	—	—	—	—	—	—
18	—	—	—	78	69	9	78	69	9	79	68	11	83	72	11
19	82	76	6	83	74	9	83	74	9	83	72	11	84	72	12
20	81	74	7	83	75	8	83	75	8	82	69	13	83	70	13
21	81	74	7	82	74	8	82	74	8	82	74	8	84	76	8
22	80	74	6	81	73	8	81	73	8	82	71	11	84	73	11
23	81	74	7	80	71	9	80	71	9	81	69	13	—	—	—
25	—	—	—	75	89	9	75	69	6	78	70	8	82	73	9
26	82	76	8	80	73	7	80	73	7	80	71	9	83	74	9
27	81	75	8	81	73	8	81	73	8	80	71	9	83	72	11
28	82	76	8	80	70	10	80	70	10	82	72	10	84	74	10
29	83	76	7	82	73	9	82	73	9	82	74	8	84	74	10
30	84	77	7	84	75	9	84	75	9	79	69	10	—	—	—
Average.	80·8	74·3	6·3	81·5	72·7	8·8	81·5	72·7	8·8	81·4	71·3	10·1	82·8	72·2	10·6

Time worked above 75° F. Wet Bulb.—For average conditions in the non-exempted rooms the time worked above 75° F. wet bulb would in the summer amount to 50 per cent. of the total working hours (*See* Fig. XXXIV.)

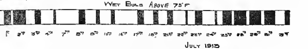


FIG. XXXIV.

Hours Worked Above 75° F. Wet Bulb Temperature in a Wet Spinning Room.

In Fig. XXXIV. the length of the strip represents the working hours (Saturdays excepted) during the month of July, 1913. The hours worked above 75° F. wet bulb temperature have been blacked out.

The average temperature in a spinning mill during the summer is as high as the maximum temperature reached daily in a weaving shed, but on other hand the difference between the dry and wet bulb temperatures averages 5 degrees in a spinning mill and 2 degrees in a weaving shed. The net result is that the time worked above 75° F. wet bulb is about the same for the two cases.

Wet Spinning with Cold Water.—Occasionally, though rarely, cold water is used in the process of flax spinning, and records were taken during three months in a mill of this type.

A reduction of the records showed that this mill averaged in summer 13 degrees above the mean outside temperature as against 23 degrees for mills working on the ordinary process. This confirms the estimate made above (page 72), namely, that the heat from the troughs and steam pipes represents from 40 to 60 per cent. according to the leas spun, of the total heat introduced.

Fig. XXXV. is a reproduction of a week's records in this mill, and it will be noticed that during the working hours the mill is little above the outside atmosphere.

In this case, therefore, the evaporation of the water sprayed from the flyers is sufficient to compensate for nearly all the heat introduced as power.

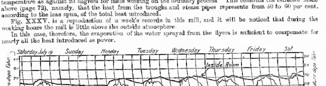


FIG. XXXV.

Flax Spinning with Cold Water.

This record was taken in a mill in which the water in the troughs was not heated. The upper record represents the temperature in the room, the lower the outside temperature.

The hot water in the troughs forms the principal source of heat in a spinning mill, and a comparison with Figs. XXIX. and XXX. will show that the temperature of a mill is some 10 degrees lower when this source of heat is eliminated.

It will be seen that during working hours this room is rarely more than 5 degrees above the outside temperature.

Foreign Spinning Mills.—As mentioned on page 50, a number of Belgian mills were visited by the Committee. In most of these the spinning rooms are considerably wider than the Irish ones. In one mill, for instance, as many as four frames were placed abreast, in other mills a large building was divided longitudinally into two halves, the preparing and spinning rooms being side by side. The division consisted of a glass partition provided with louvres or windows through which moist warm air from the spinning room could be passed into the preparing room. The lighting of large buildings of this kind is a difficult problem and little appears to be gained by such an arrangement.

The manager of the Société Anonyme Linière Gantoise was kind enough to supply the Committee with a full set of thermometer readings taken during the summer 1913. It is customary in this mill to take several daily readings in each of the forty rooms which the mill comprises. The average results for the six wet spinning rooms are given in Table 27.

TABLE 27

MEAN DRY AND WET BULB TEMPERATURES IN THE SPINNING ROOMS OF A BELGIAN MILL.

Room.	Temperature in ° F.											
	June.			July.			August			Summer.		
	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference.	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference.	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference.	Dry Bulb Temperature.	Wet Bulb Temperature.	Difference.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
"a" -	81·7	75·4	6·8	81·0	75·5	5·5	80·8	74·7	6·1	81·2	75·2	6·0
"b" -	84·0	77·5	6·5	83·6	77·6	6·0	83·8	77·5	6·3	83·8	77·5	6·3
"c" -	81·4	76·3	5·1	82·3	78·3	4·0	82·4	76·5	5·9	82·0	77·0	5·0
"d" -	81·7	77·9	3·8	81·1	77·8	3·3	84·3	76·5	7·8	82·4	77·4	5·0
"e" -	79·4	74·0	5·4	78·0	73·5	4·5	78·2	73·1	5·1	78·5	73·5	5·0
"f" -	78·8	73·4	5·6	77·9	73·3	4·6	78·6	73·0	5·6	78·4	73·2	5·2
Average -	81·2	75·8	5·4	80·6	76·0	4·6	81·3	75·2	6·1	81·0	75·6	5·4

It will be seen that the average dry bulb temperature in these rooms during the summer is 81° F. and the average difference between the wet and dry bulbs 5·4 degrees, or the temperature is 1 degree lower than the average for the experimental Irish mills (*see* Table 2D, and the difference between the wet and dry bulb the same (*see* Table 17, page 73).

Belgium in summer is about 5 degrees or 6 degrees hotter than Ireland, but it is noticeable that the temperature in these rooms was practically independent of the outside temperature, ranging only over 2 degrees for a variation of the outside temperature of 25 degrees.

Experiments on Ventilation.

Investigations upon the direction and velocity of air-currents and the distribution of temperature were carried out in five spinning-rooms, namely, "Q," "S," "U," "I," "R," while in the two last-named mills continuous records were taken.

Experimental Methods.—Two anemometers, one 4 inches, one 6 inches, were used, and from their readings the outlet flow from each fan and the air passing in or out through the open windows were estimated. In addition to these, a number of lightly constructed wind vanes (weighing only $\frac{1}{16}$ oz. and so delicately balanced as to turn to currents of $\frac{1}{16}$ of a mile per hour) were placed in the room (1) At the floor level, (2) At the level of the top of the frames, and (3) Close to the ceiling; and these measured the horizontal component of the air-currents.

In this way the circulation in the room was mapped out; and the general trend of the currents was confirmed by a smoke apparatus.

Stands were erected at intervals in the rooms, and carried thermometers fixed vertically one above the other at intervals of a foot. Measurements of the temperature of the incoming and outgoing air, the inside and outside wet and dry bulb thermometers, and the temperature of the water in the troughs were made. Where possible the horse-power used was also ascertained.

Room "R."—This is a large spinning room (123,000 cubic feet capacity), situated on the third floor of the mill between a preparing-room and a reeling-room. A plan and elevation of the arrangement of the frames windows, and fans are given in Fig. XXXVI.

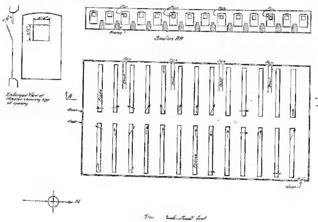


FIG. XXXVI.

Plan and Elevation of Room "R."

The positions of the windows, frames, fans, &c., are shown. The arrows indicate the direction of the internal air circulation on the 8th August, to which day Fig. XXVII. refers.

The room is 136 ft. by 70 ft. and 13 ft. 6 ins. high; it contains twenty-six frames. The leas spun range from 16's to 32's.

This mill is of modern construction and has been carefully planned with a view to improving the conditions under which work is carried out.

The spinning room is very high and well lighted, the main pass and stands are wide. It will be noticed, however, that the windows cannot be fully opened, only a small square being movable, and that the fan capacity is inadequate for so large a room. As a result this mill reaches high temperatures.

The leas spun varied from 16s to 32s, and the temperature of the troughs from 120° F. to 170° F.

The direction of the wind vanes at the top of the frames and on the floor is indicated in the figure for 8th August, 1913.

The windows face West and East and on the days in question there was a light air blowing from a northerly direction or along the length of the room, and in addition to the circulation due to the fans there was an appreciable amount of natural ventilation.

It will be seen from Fig XXXVI. that only a small part of the windows was movable and the maximum cross-sectional area of the incoming current was limited to two square feet, or one-twentieth of the window area.

In Fig. XXXVII. the positions of the openings and fans and the quantity of incoming and outgoing air at each are indicated.

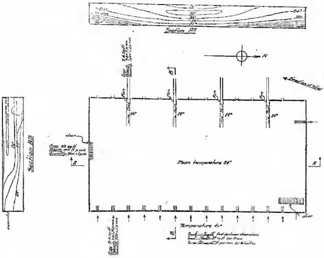


FIG. XXXVII.

Ventilation of Room "R." First Test.

Fig. XXXVII. shows the distribution of inlet and outlet currents in this mill. During the test all doors and windows where kept open to their fullest extent, but as already mentioned in connection with Fig. XXXVI. the window openings in this mill are rather restricted.

The velocity of the air through the inlets averaged 200 feet per minute.

The air entering the room was in excess of the capacity of the fans and the balance passed out through the windows next the fans.

Figs XXXVIII A *and* B *give the longitudinal and transverse distribution of temperature. Temporary columns were placed at intervals in lines running along and across the shed; each of these carried thirteen thermometers placed vertically one above the other at intervals of a foot. The isotherms in these figures are derived from the readings thus obtained.*

At the centre of the room the temperature near the floor was 82° F. and rose to a maximum of 88° F. six feet above the floor level. Owing to the inward current through the large doors at each end of the room, the temperatures here were considerably lower (i.e., 72° F. at the floor, 82° F. six feet above the floor, and 84° F. at the ceiling).

The transverse section B shows that the slow current of cool air entering on the east side of the room mixes at once with the atmosphere of the room, lowering and equalising the temperature on this side. There is a general drift of the atmosphere of the room towards the inlet fans and the air passing slowly across the room becomes heated and stratified according to temperature.

Two large doors, one at each end of the room, and practically all the casements were open. Each of the four fans delivered about the same amount of air and, apart from the effect of outside wind, the inlet velocity at the various openings was about constant. In the present case the air was entering from the East side, and the excess over the capacity of the fans passed out at the West side. The distribution of temperature along and across the room is shown by isothermal lines on the sections AA, BB. The drop at each end of the room is doubtless to be attributed to the large volume of fresh air entering the doors. It should be noted that the air, which comes in at 61° F., leaves the fans at a temperature approaching the maximum in the room. Whatever the trend of the air currents, therefore, it is clear that no appreciable cooling effect is lost by short-circuiting between fans and the opposite windows.

The actual circulation is difficult to represent, being three-dimensional and in general not parallel to any given cross-section of the room. Certain sections have therefore been chosen arbitrarily to illustrate the main facts.

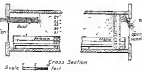


FIG. XXXVIIIA.

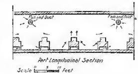


FIG. XXXVIIIB.

Figs. XXXVIII. A and B give the circulation of the air within the mill "B" as indicated by small wind vanes and traced out by aid of the smoking apparatus.

The cold air entering the windows owing to its large difference of density mixes rapidly with the air of the room, and at a few feet from the window no cold draught is noticeable.

The velocity of the air current, which was about 200 ft. per minute in the window opening, drops to three or four feet per minute at a distance of ten feet away, and beyond this is almost imperceptible.

The outlet duct draws air equally from all directions and the outlet current only acquires an appreciable velocity within a few feet of the duct opening.

It is shown in Figs. XXXVIII A and B. that the stream of air enters the narrow window openings at about 200 feet per minute, but widens and slows down in velocity almost at once. A few feet beyond the opening its speed is scarcely appreciable and its temperature corresponds to the general distribution in the room at the place considered. The fan inlet draws from all directions and the currents a few feet from the duct opening are quite negligible.

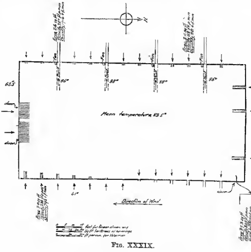


FIG. XXXIX.

Ventilation of Room "B." Second Test.

As in Fig. VI. the width of the shaded spaces is proportional to the area of the openings, the length of the lines to the velocities of the currents at the inlets and outlets; the areas shaded on the diagram are therefore proportional to the quantity of air admitted. Outlet currents are left unshaded.

On this occasion there was a natural circulation along the length of the room considerably larger than that induced by the fan. The air rising up the mill staircase passed into the spinning room through two large doors and out again through another door at the opposite end. These conditions are of course unusual.

The distribution and arrangement of the inward and outward circulation in the same mill are shown in Fig. XXXIX. for another day. There is now a natural circulation along the shed which is comparable with the total capacity of the fans; and as a result the temperature of the room was slightly cooler than under the conditions shown in Fig. XXXVII., in spite of the fact that it was rather hotter outside.

Room "S."—With regard to the five other rooms investigated in a similar manner, it will be sufficient to point out a few of the more interesting features.

Fig. XL., Room "S," shows a plan and elevation of a spinning-room, which in the past has been reputed to be exceptionally hot.

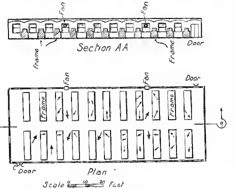


FIG. XL.

Plan and Elevation of Room "S."

This is a wet spinning room of old construction. The machinery is crowded, the main pass and stands narrow, and the room low. The process carried out is coarse spinning (25 to 30 leas). As a result, although the fans are powerful, the room is very hot. The arrows give the direction of the air currents as indicated by small wind vanes.

Since the experiments were carried out, however, it has been completely reorganised and modernised. The room is low and somewhat crowded, and is ventilated by two exhaust fans

Measurements were first made with most of the windows closed, and the remainder open by only a small amount, the customary arrangement of the spinning-master. The effect of this limitation of the inlet openings is to restrict the volume of air drawn out by the fans, and to induce a relatively high velocity in the incoming current, which under the circumstances is independent of the position of the inlet. The entire room is, in fact, maintained slightly below atmospheric pressure, and the inlet velocity at any point is determined by the constant-pressure difference which exists between the air in the room and the external air. This effect is clearly shown in Fig. XLI., where, as before, the length of the shaded spaces represents the velocity of the air-currents.

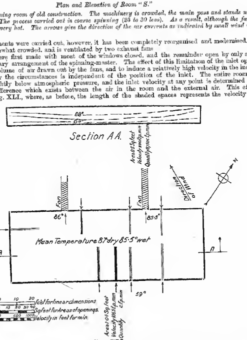


FIG. XLI.

Ventilation in Spinning Room (No. "S"). First Experiment.

This figure represents the distribution of ventilation as produced by the arrangement of window openings usually adopted by the spinning master.

The total inlet area is inadequate for the capacity of the fans, and as a result the quantity of air passed through the room is reduced, and the inlet currents take the form of narrow streams of high velocity. As in the previous figures, the width of the shaded areas represents the area of the openings; the length of the shading is equal to the velocity of the current and therefore the shaded area on the diagram is proportional to the quantity of air passing in or out. It will be noticed that under these conditions the air entering from each opening has approximately the same velocity, irrespective of the position of the openings. Also, that although windows were open on each side of the fans, there is little short circuiting of the air currents, for the air expelled by the fans is at the average temperature of the room.

Fig. XLI.A gives the distribution of temperature along the room as derived from the readings of several groups of thermometers each arranged on temporary wooden columns placed near the centre line of the room. Each column carried ten thermometers. It will be noticed that there is four degrees difference between the temperature of the air near the floor and near the ceiling. At the centre of the room the maximum temperature is reached at a height of five feet, at the ends of the room only at the level of the ceiling.

The internal circulation was again determined by smoke, and by wind vanes placed about the room. The direction of the air currents, which is indicated in Fig. XL., is shown diagrammatically in Fig. XLII.

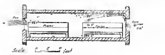


FIG. XLII.

Fig. XLII. represents diagrammatically the current of air from one of the windows; owing to its high velocity the cold air keeps near the ceiling, and its velocity remains appreciable up to the centre of the room.

With such an arrangement as this, it is possible to cool locally any part of the room by directing through it a large proportion of the total current, or to arrange the openings in such a manner as give a fairly uniform temperature. The restriction of the inlets is, however, bound to reduce considerably the volume of air circulated.

It will be noticed that, although it is unsatisfactory owing to possible short-circuiting to have windows near the fans open, the loss is not very serious. In the present case, for instance, although one of the fans had partly open windows on either side of it, the air drawn out was nearly at the maximum room-temperature.

Fig. XLIII., shows the volume and velocity of the air passing through the same room when all the windows along one side were open to the fullest extent allowed by their construction.

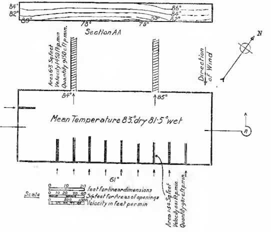


FIG. XLIII.

Ventilation of Room "S." Second Test.

*This figure refers to the same room as **Fig. XLI.**, but with all the windows on the side opposite to the fans open to their fullest extent.*

Although the day was slightly hotter, the temperature of the room is four degrees cooler. It may again be noted that the velocity of the incoming air is independent of the position of the openings relative to the fans.

Fig. XLIII.A shows the distribution of temperature along the room. The temperature is 78° F. at the floor level and 86° F. near the ceiling. This distribution is nearly uniform along the room.

The total inlet area was in this case three times as great as in Fig. XLI. The inlet velocity is decreased by 30 per cent., while the total ventilation volume is considerably increased. The nature of the general circulation is not altered, but the wider and more slowly moving streams of air from the windows mix more rapidly, and only retain an appreciable velocity to a distance along the ceiling of about half the length of the frames (see Fig. XLIV.). With the open windows the room was 4 degrees cooler, although the outside temperature was 2 degrees hotter.

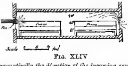
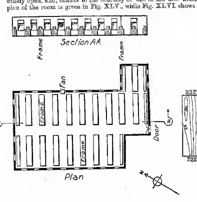


FIG. XLIV

Fig. XLIV. illustrates diagrammatically the direction of the incoming current from a window. Comparing this figure with Fig. XLII. we see that the incoming air mixes rapidly with the air of the room; at three or four feet from the window the velocity is inappreciable. It will be noticed that on this day the wind direction was directly opposed to the direction of the circulation induced by the fans and tended to check the air and reduce the cooling effect.

Room "U."—It appeared of interest to study the conditions prevailing in a room when all the windows are widely open, and, thanks to the courtesy of one of the mill managers, it became possible to carry this out. A plan of the room is given in Fig. XLV., while Fig. XLVI. shows the inlet and outlet currents.



Scale 0 10 20 feet for linear dimensions

FIG. XLV.

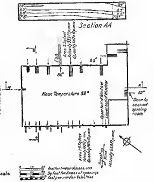


FIG. XLVI.

FIG. XLV.

Spinning Room "U."

The figure gives the plan and elevation of a spinning room similar in many respects to Room "S" shown in Fig. XL. The room is low and rather crowded with machinery and is ventilated by a single fan. The leas spun range from 100's to 190's.

FIG. XLVI.

Ventilation in Room "U."

For this experiment both upper and lower sash of all the windows were opened to their fullest extent. The wind was directly opposed to the direction of the circulation induced by the fan. Under these conditions the air entered through the windows on the windward side and only the excess over the fan capacity escaped through the windows on the opposite side. The inlet velocity averaged 400 feet per minute, the current through the windows on the leeward side was slow and fluctuating, occasionally air was entering through the lower half of the window and escaping through the top.

Figs. XLVI. A and B give the distribution of temperature along and across the room. The temperature was 78° F. near the door and 84° F. near the ceiling; the longitudinal and transverse distributions are nearly uniform throughout the room.

The room was on the fourth floor with reeling-rooms above and below it. On the east side it adjoined another spinning-room, with which it was connected by an open doorway. One fan was available for ventilation purposes. The total area of the openings was 40 square feet, compared with 5 square feet and 16 square feet respectively for the two cases dealt with in Room "S" (Figs. XLI. and XLIII.). Under these circumstances a slight wind becomes the principal factor in the ventilation, and the action of the fans is less important. Measurements showed that about one-quarter of the air coming in to windward passed out through the fan, the remainder escaping by the windows on the opposite side of the room. Owing to the large area of these openings, the outward current was slow, irregular and difficult to measure. The windows were open both top and bottom, and the direction of flow through one or other opening was frequently reversed, a condition characteristic of a sheltered window in a room in free communication with the outside air.

The free opening of all windows is, of course, possible only on warm and relatively calm days, and under such circumstances the total circulation induced will be more than equivalent to that which would be produced by the fan installation. The natural ventilation, however, does not necessarily add its effect to that of the fan. In the above room, for example, on the days considered, the circulation induced by the fan was in the opposite direction to the natural circulation, and the effect of the two together was much smaller than the sum of what either might have produced alone

The distribution of temperature in this room is shown in Fig. XLVI.; the temperature is lower and the distribution somewhat more uniform than in the previous cases

The rooms so far considered illustrate the ordinary practice of the flax spinning trade. It is possible, however, by careful attention to details of construction and arrangement to reduce considerably the maximum temperatures which a room reaches in summer.

Mill "Q."—A more general discussion of the steps which may be taken in this direction will be dealt with later, but it is of interest to study the conditions in a spinning-room where many special arrangements have been introduced, namely, Room "Q." This room, which is shown in Fig XLVII., is situated on the fourth floor of a large mill, between a fine preparing room and the flat roof of the mill.

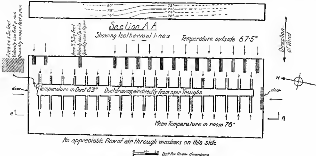


FIG. XLVII.

Ventilation of Room "Q."

This mill is of modern construction. The main pass and stands are wide and the height of the room is above the average. The frames are driven by electric motors. The room is ventilated by a single large fan drawing air through a duct which runs the entire length of the room and discharging it into a vertical shaft 6 feet square. The air is drawn from above the trough covers through the branch ducts shown in Fig. XLVIII.

During the test the wind was easterly and practically all the air entered through the 16 windows open to windward, the current through the windows on the opposite side of the room being small and variable in direction. Fig. XLVIIA. gives the temperature distribution along the room.

The leas spun range from 40's to 150's, while the average temperature of the troughs is 160° F. The frames are electrically driven, a separate motor being geared to each. The motors are air cooled, the

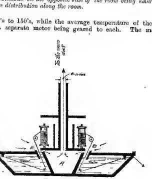


FIG. XLVIII.

Construction of Creel and Troughs in Spinning Room "Q."

In this mill the tops of the spinning frames are arranged to form ventilating ducts; the space A between the troughs is boarded in and an air duct is also provided between the rove bobbins. The air passes into these ducts through narrow slots "B" placed immediately above the trough covers. At the end of the frames the branch ducts are connected to a main duct running the entire length of the spinning room.

The air extracted in this way is considerably above the average temperature of the room and it carries with it any steam escaping from the troughs. This method of ventilation is therefore very effective.

heated air in summer escaping by a duct specially provided for the purpose 92 kilowatts were supplied to this room on the days on which the observations were taken, but owing to the special cooling mentioned above only about 76 kilowatts were actually effective in heating the room. Rather more power is said to be required on some occasions.

The heating effect corresponding to the loss of power in the main shaft and belting of an ordinary mill is eliminated by the use of this arrangement of motors.

A rectangular air duct runs along the centre of the room. Its section near the fan is 5 feet by 4 feet, and diminishes gradually along the room. The space between the rows of bobbins is boarded off, and forms a long narrow duct which runs the entire length of the frame. (*See* Fig. XLVIII.)

Air is drawn into the ducts through the slots BB placed above the covers of the troughs, and is led thence to the main duct, which communicates with a vertical shaft, about 6 feet by 6 feet, extending to the top of the building. The hot air surrounding the troughs, the temperature of which is far above that of any other part of the room, is thus removed before it mixes with the surrounding air. This arrangement is an example of the general principle that if a given volume of fluid can be removed, the maximum cooling is effected by choosing the hottest part of the fluid for removal. In a similar manner, where dust is generated, every effort is made to remove it before it spreads into the atmosphere of a room.

During the tests made in this room 35 of the 40 windows were open. A general idea of the circulation maintained is given in Fig. XLVII., and the temperatures in the centre of the room are also indicated.

All the frames were fitted with splashguards, and the floors consequently were dry. The volume of air drawn through the duct amounts to 18,300 cubic feet per minute, or seven changes per hour.

The room is high and the main pass much wider than usual. As a result of the well thought out arrangement described above, the atmosphere of the room is both cooler and dryer than in other rooms where similar goods are manufactured.

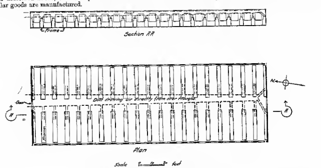


Fig. XLIX.

Plan and Elevation of Room "Q."

This is a large spinning room of modern construction and ventilated by a duct system. The intensity and direction of the air currents are shown in Fig. XLVII.

The mean monthly temperatures for working hours have been given in Table 25 for two rooms ventilated in this manner, and are compared with the corresponding figures for average rooms.

In summer, the dry bulb temperature is two degrees lower and the wet bulb temperature five and a half degrees lower than in the comparison rooms, Nos. 103 and 109. Room "P" is of older construction than Room "Q" and is not driven electrically. The system of ventilation, however, is the same.

Table 28 compares the daily wet and dry bulb temperature readings for Room "Q" during August with the corresponding figures for an average room.

TABLE 28.

COMPARISON OF DAILY DRY AND WET BULB TEMPERATURES IN AN EXEMPTED AND ORDINARY MILL DURING THE MONTH OF AUGUST.

	Average Room "103."			Exempted Room "Q."		
(1)	Dry Bulb Temperature. (2)	Wet Bulb Temperature. (3)	Difference. (4)	Dry Bulb Temperature (5)	Wet Bulb Temperature. (6)	Difference. (7)
August 1 - .	82	78	4	77	70	7
" 4 . .	75	70	5	76	68	8
" 5 - -	84	80	4	77	69	8
" 6 - -	80	76	4	77	69	8
" 7 . .	82	77	5	77	69	8
" 8 . .	80	75	5	77	69	8
" 11 - -	78	74	4	76	68	8
" 12 . .	81	76	5	76	68	8
" 13 - -	82	77	5	78	70	8
" 14 - -	81	77	4	77	70	7
" 15 - -	82	78	4	79	72	7
" 18 - -	83	78	5	76	68	8
" 19 - -	81	76	5	76	69	7

TABLE 28—*continued.*

(1)	Average Room "103." Dry Bulb Temperature. (2)	Wet Bulb Temperature. (3)	Difference. (4)	Exempted Room "Q." Dry Bulb Temperature. (5)	Wet Bulb Temperature. (6)	Difference. (7)
August 20 - -	84	79	5	77	69	8
" 21 - -	81	77	4	78	70	8
" 22 - -	79	75	4	76	69	7
" 25 - -	79	74	5	76	69	7
" 26 - -	82	75	7	78	71	7
" 27 - -	84	78	6	77	70	7
" 28 - -	83	78	5	78	70	8
" 29 - -	79	74	5	78	71	7
Average . - -	81	76	5	77	69½	7½

Laboratory Experiments on Ventilation.

In addition to the work described above, a series of experiments on ventilation was carried out by Mr. H. G. S. Delepine, in Manchester, for the Committee.

A room at the University was fitted with an exhaust fan and means of heating by gas stoves. This room was of moderate size, the capacity being about 15,000 cubic feet. A plan and section are shown in Fig L.

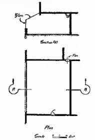


Fig. L.

Fig. L. shows a plan and section of the room used for the experimental work described on page .

Several sets of experiments were made to determine the effect of increased ventilation on the temperature inside the room. The various factors influencing the results were measured, and were controlled in the following way:—

The amount of heat entering (corresponding to the heat given off from the troughs, machinery, &c. in a spinning-room) was calculated from the calorific value of the gas and the amount burnt per minute. The loss of heat by radiation through the walls and windows was estimated by measuring the temperature ultimately reached by the air in the room when all ventilation was stopped. This was done for different rates of heating, the quantity of gas supplied per minute being varied, and the results obtained are shown in Fig. LI.

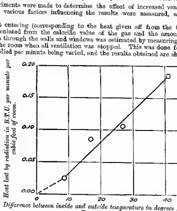


Fig. LI.

Fig. LI. gives the results of experiments carried out in the room shown in Fig. L. to determine the relation between the outward flow of heat by radiation through the walls, &c., and the temperature difference between the room and the outside air.

The flow is nearly proportionate to the temperature difference and corresponds to about 0·005 B.T.U. per degree Fahr. difference per minute per cubic foot of room.

For the size of the room, the amount of heat radiated will be found to be very great, and this is to be explained by the fact that the whole of one side of the room was glazed.

Anemometer measurements of the amount of ventilating air were taken at the fan, and as the latter was driven electrically it could be regulated to give a varying velocity through the outlet duct, the actual limits of variation being 450 and 970 feet per minute.

Temperatures at the inlet and inside the room were measured, using wet and dry bulb thermometers, those inside the room being placed out of the direct draught at a height of 6 feet from the floor. The air was kept moist by spreading about the room large sheets soaked in water, which were occasionally sprayed.

The results of one set of experiments are shown in Table 29 and Fig. LII.

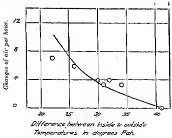


FIG. LII.

The curve shows the number of changes as calculated. Results of experiments are shown thus :—o.

Fig. LII. shows the number of changes of air required to reduce the temperature of the room shown in Fig. L. to any given amount above the temperature of the outside air when the heat supply amounts to 0·18 B.T.U. per minute per cubic foot of room capacity. The individual points give the experimental results.

TABLE 29.

COMPARISON OF THEORETICAL AND ACTUAL COOLING PRODUCED BY VENTILATION.

Temperature difference = Temperature inside Room minus Temperature of incoming Air.	Actual changes of Air per hour (measured).	Heat entering Room in B.T.U. per minute per cubic foot of Room.	Heat escaping by Radiation in B.T.U. per minute per cubic foot (*see* Fig. XX.).	Net Heat removed by Ventilation in B.T.U. per minute per cubic foot.	Heat removed by 1 cubic foot of Air.			Calculated Number of Changes per Hour or 60 H/h.
					By the Heated Air.	By the Vapour in the Air.	Total.	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
T	Average.	H_T	H_R	H			h	A
34° F.	2·7	·18	·15	·03	·61	·31	·92	2·0
30° F.	4·2	·18	·13	·05	·54	·29	·83	3·6
26° F.	5·7	·18	·11	·07	·47	·16	·63	6·7
22° F.	7·1	·18	·09	·09	·40	·09	·49	11·0

The Temperature of incoming Air was 50°.

The humidity of incoming Air was 68 per cent.

The humidity of the Air inside the room was 40 per cent. (average).

Note on Calculation of Table.

To obtain the theoretical number of changes of air per hour, the following equations were used :—

Where H_T = *total heat entering room in B.T.U. per minute per cubic foot of room.*

H_R = *heat escaping by radiation in B.T.U. per minute per cubic foot of room.*

$H = H_T - H_R$ = *heat removed by ventilation in B.T.U. per minute per cubic foot of room.*

T = *Difference between the temperature inside the room and that of the incoming air in degrees Fah.*

D = *Difference between the number of grs. of moisture per cubic foot in the air inside the room, and in that of the incoming air.*

A = *the number of cubic feet of air passing through the room per hour per cubic foot of the room, or the number of changes of air per hour.*

Then $60H = (A \times T \times wt.\ of\ 1\ cubic\ foot\ of\ air \times specific\ heat\ of\ air) + (A \times \frac{D}{7000} \times latent\ heat\ of\ 1\ lb\ of\ steam\ at\ about\ 80°)$.

$= A\ (\cdot 018T + \cdot 15D)$.

Or $A = \dfrac{60H}{\cdot 018T + \cdot 15D}$.

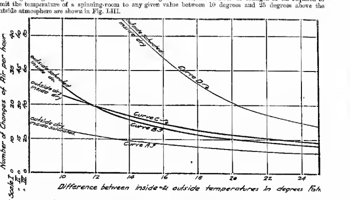
The heat supply to the room was kept constant, and the rate of ventilation varied. The number of changes of air per hour and the corresponding differences between the temperature inside the room and that outside are tabulated in Table 29. The theoretical number of changes to maintain the same temperature difference have been calculated, and are inserted in the table for comparison. Exact experimental determinations are difficult to obtain, but the diagram clearly shows that it is possible to calculate with reasonable accuracy the amount of ventilation required to produce a given cooling effect.

Theoretical Effect of Ventilation.

Proceeding on the lines indicated in Table 29, the calculated cooling effect of increased ventilation in spinning-rooms will now be considered.

The amount of heat entering such a room varies considerably, depending mainly upon the horse-power consumed by the frame and the temperature of the troughs. In the mills investigated the heat entering the room expressed in B.T.U. per minute per cubic foot of room, varied from 0·20 in Room "R" to 0·35 in Room "S." In the following calculations values of 0·20, 0·30 and 0·40 have been taken. The radiation through the walls, floor and ceiling of a spinning-room accounts for only a small proportion of this heat. If estimated from the coefficients usually adopted,* it accounts for less than 10 per cent. of the total heat entering the room under average existing conditions. This conclusion has also been confirmed experimentally.†

Using the figures given above for the heat entering the room, the number of changes of air required to limit the temperature of a spinning-room to any given value between 10 degrees and 25 degrees above the outside atmosphere are shown in Fig. LIII.



Assumptions made in calculating the curves :

Heat entering room per cubic foot of room { Scale I. 0·20 B.T.U. per min.
Scale II. 0·40 " "
Scale III 0·40 " " }

Outside humidity when "dry" 50 °/ₒ saturated.
Inside humidity when "dry" 64 °/ₒ saturated.
Radiation through walls, &c = 10 °/ₒ of heat entering, when temperature difference = 25°.

Fig. LIII.

Fig. LIII. shows the calculated number of changes of air required to reduce the temperature of a spinning room to any given amount above the temperature of the outside air. Different curves have been plotted for different atmospheric conditions, the most usual combinations being shown by the heavier lines. The assumptions on which the calculations for these curves are based are given above the diagram.

The number of changes required depends of course on the quantity of heat introduced. Scale II. corresponds about to an average mill, Scale III. to a coarse mill where the machinery is very crowded, and Scale I. to a fine mill of modern construction.

The values used in the calculations were, specific heat of air, 0·237; latent heat of water, 1050.

The loss by radiation was taken as 10 per cent. of the total heat entering the room for a temperature difference of 25 degrees. Various combinations of inside and outside conditions were considered, the extreme cases being (*a*) entering air, dry; outgoing air, saturated (see curve A); and (*b*) entering air, warm and wet; outgoing air, 64 per cent. saturated (see curve D).

To illustrate the cooling effect of the ventilating air, shown graphically in Fig. LIII., a particular case has been chosen.

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* B.T.U. loss per hour per square foot per degree difference between inside and outside air.

8 inch brick wall	0·46 B.T.U.
16 " " "	0·26 "
24 " " "	0·19 "
1 square foot single window	1·00 "

† To obtain the amount of heat escaping from a spinning-room by radiation through the walls, floor and ceiling, steam was left on to heat the troughs in a room after the fans and frames had been stopped. The temperature of the room was allowed to rise until the heat radiating from the trough balanced that escaping through the walls, &c. A maximum temperature of 108° F. was reached in this case and maintained for several hours.

When the temperature of the room had reached a steady value, the outflow of heat from the troughs was obviously equal to the outflow through walls, floor and ceiling. Now the inflow from the troughs can be calculated from the experiments on conduction given below, and amounts to 4,400 B.T.U. per minute.

An estimate of the effective conductivity of the walls floor and ceiling is thus available. The numbers obtained in this way are somewhat in excess of the coefficients quoted above. Using the generally accepted coefficients, the heat passing through walls, floor and ceiling would be estimated at 6 per cent. of the total, while the experimental values give 8 per cent. As already pointed out above, the exact value is not of interest, as it will vary from room to room. It is, however, important to remember that more than 90 per cent. of the total heat must be carried away by ventilation, natural or artificial.

TABLE 30.

THEORETICAL EFFECT OF INCREASED VENTILATION UNDER VARIOUS CONDITIONS.

Condition of Air.		Percentage Humidity.		Difference between Inside and Outside Temperatures.		
Outside.	Inside.	Outside.	Inside.	Normal Ventilation.	Ventilation increased by 50 per cent.	Ventilation increased by 100 per cent.
(A) Dry - . .	Saturated	50 per cent.	100 per cent.	25°	16°	11°
(B) Saturated - -	Saturated	100 ,,	100 ,,	25°	17°	13·5°
(C) Dry - . .	Dry	50 ,,	64 ,,	25°	18°	13°
(D) Saturated - -	Dry	100 ,,	64 ,,	25°	20°	17·5°

The figures in Table 30 have been calculated for a room in which the temperature was originally 25 degrees higher than that of the outside air. Two cases have been worked out; first, when the amount of ventilating air is increased by 50 per cent., and secondly, when it is doubled. The resulting temperature difference is given, and it will be seen that when the ventilating air is doubled, even under the worst conditions likely to occur, the difference between the temperature of the air inside the room and that outside is decreased from 25 degrees to 17 degrees, while under the best conditions it is decreased from 25 degrees to 11 degrees. Expressed otherwise as an average figure, if the amount of ventilating air is doubled, the difference between the inside and outside temperature is nearly halved.

It should be remembered, however, that if the room has a large surface through which the heat may escape, either because of a cool room above or below, or for any other reason, then, as the temperature in the room itself is decreased, the amount of heat escaping by radiation will be diminished, and an increasing amount must be dealt with by ventilation. For this reason increased ventilation will have rather less effect on such a room than on one having a smaller radiating surface.

It will be noted that, all other conditions being the same, the amount of ventilating air required to maintain any specified temperature difference varies directly with the amount of heat entering the room. The curves (Fig. LIII.) may therefore be readily adapted to suit any particular case where this amount is known.

EXPERIMENTS ON TROUGH INSULATION.

Figures have already been given for the quantity of heat entering existing rooms (see page 72). Expressed as a percentage, the amount entering by the various sources has been found to be approximately as follows:—

Power to frames	- - - - - - -	30 per cent.
Heat due to operatives	- - - - - -	2 ,,
Radiation from steam pipes	- - - - -	3 ,,
,, ,, troughs	- - - - - -	45 ,,
Spray from flyers	- - - - - - -	20 ,,

It will be observed that by far the largest individual source of heat is the radiation from the troughs, and also that this radiation and the spray from the flyers together account for over 60 per cent. of the total heat entering the room. Since neither of these quantities can be calculated directly from existing data, special experiments were carried out to estimate them.

The heat lost in the spray was obtained by measuring the amount of water fed into the troughs, and therefore the amount drawn out by the rove. This was done in a room spinning leas from 25's to 50's. The actual quantity measured varied from 0·83 to 0·53 cubic feet per hour for an 18-feet frame; so that, assuming the sprayed water to cool from a temperature of 190° F. to 80° F., the average heat given up will be equal to 4 B.T.U. per minute per linear foot of frame. This figure was found to vary considerably even for the same set of frames, and can therefore only be used as a rough guide.

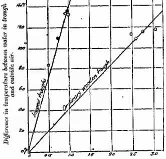

FIG. LIV.

Heat lost by radiation in B.T.U. per minute per square foot of superficial area of trough.

Fig. LIV. shows the heat lost by radiation, &c., from spinning troughs, the lower line referring to a wooden trough such as is commonly in use, the upper line to a specially constructed metal trough insulated with hair felt or slag wool.

To obtain the heat lose due to radiation from the troughs, one was constructed similar in cross-section to those actually in use, and 7 feet 6 inches long. A ½-inch pipe was laid inside, with one end connected to a steam main and the other open to the air. The trough was filled with water, and was heated by dry steam blown into this pipe. When the temperature of the water had ceased to rise, careful measurements were made of the steam condensed in the pipe per minute and of the mean temperature of the water inside the trough. Since, the temperature of the water remaining constant, the heat given up by the steam in condensing must balance the heat lost by the trough radiation, a value for this latter could now be found. The results obtained in this way are shown plotted in Fig LIV., and it will be noticed that for a temperature difference of 110° the heat lost by radiation per square foot of external area of trough is approximately 3 B.T.U. per minute, or ·027 per square foot per minute per degree temperature difference, using this number the quantity of heat entering any spinning room can be readily approximated.

Since so large a proportion of the total heat in the room comes from the troughs, it is of no little interest to investigate methods by which this flow could be checked. Accordingly experiments were carried out using lagged troughs to limit the loss. Two types were used, the radiation being found to be practically the same for both. The first was made similar to the wooden trough in common use, but lined with metal, with a layer of slag wool, ½ inch thick, inserted between the lining and the wood. In the second the outside wooden covering was replaced by metal, the metallic lining retained, and the slag wool replaced by a 1-inch layer of hair felt. The whole trough was solidly finished, and the felt entirely enclosed.

The results of these experiments indicate that a considerable reduction in the heat loss is effected by the use of lagged troughs amounting, in fact, for the conditions under which the observations were made, to nearly two-thirds of the loss from the wooden trough. Even the combination of a lagged lid with the ordinary wood body was found to decrease this lose by nearly one-half. These observations were made with comparatively still water, the only movement being caused by the convection currents round the steam pipe. Further experiments carried out with the water mechanically stirred and at a uniform temperature showed that for the lagged and partly lagged troughs, the results were unaltered, but for the plain wood, the loss appeared to be reduced, so that the saving effected by using a completely lagged trough was not greater under these conditions than about one-half of the heat loss from the wooden trough. In practice, therefore, since the rove always causes a slight movement in the water, the saving will probably lie between one-half and two-thirds of the present loss.

This reduction in the radiation from the troughs represents from 1½ to 2 lbs. of coal burnt per hour per frame, so that the cost of the lagging would probably be balanced by the saving in fuel. The temperature in an average room would also be appreciably reduced. The actual saving in heat and reduction in temperature cannot be accurately forecasted, for the leakage of steam round the lids, the level of water in the troughs, and many other conditions are of importance.

Typical Methods of Ventilation.

With a view to reducing the temperature it is of course desirable that the room should be surrounded on all sides by surfaces little above atmospheric temperature; and for this reason the spinning rooms should not be one above the other, but each spinning room should be between two preparing rooms, or situated at the top of the building with a preparing room or reeling room below it.

Whereas, however, in a weaving shed roof and floor areas are the principal factors in fixing the temperature, in a spinning room they are relatively unimportant, and artificial ventilation is the main factor.

To secure uniform conditions in any enclosure, no part of it must be at any considerable distance from the fresh air inlets, and the arrangements must be such that each part of the enclosure receives a due proportion of the total fresh air supplied.

In weaving sheds, where the air must be conditioned before entering, it is usually convenient to have a central conditioning plant, and to distribute the air by means of ducts. In a wet spinning room the ratio of fresh air supplied per hour to the cubic contents of the room is generally large, and the incoming air does not require conditioning. Under these circumstances it is more convenient to use exhaust fans installed in the window openings and dispense with the cost and loss of power involved by a duct. The distribution of the air may then be regulated by adjusting the size and position of the inlet openings. The shape of the spinning room lends itself to this arrangement, and with the inlets equally spaced along one side of the room and extraction fans on the other the distribution leaves little to be desired.

The area of the inlets should not be less than three times the area of the fans, or the output of the fans would be appreciably reduced. The fans should be equally spaced along the opposite wall but their position is relatively less important than that of the inlets.

A fan draws equally from all directions and projects the air in the direction in which it is turned. (*See* Fig. LV.)*

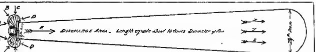

FIG. LV.

Diagram showing effect of an Electric Fan. Suction and Discharge Areas drawn to scale from actual observation.

Fig. LV. reproduced from Plate VIII. of the Second Report of the Committee on Ventilation of Factories and Workshops [Cd. 3553]. The figure indicates a longitudinal section of the area in which there is a draught exceeding 2 feet per second as measured by an anemometer, the direction of the current being indicated by arrows.

In this figure the enclosed space is a section of the area within which the velocity of the current exceeds 2 feet per second. It will be noticed that this appreciable draught extends on the discharge side for a distance twenty times as great as on the suction side. A plenum fan therefore requires distribution ducts which are unnecessary in the case of an exhaust fan.

The latter tends primarily to reduce the pressure in the room, and at every inlet whether near or remote from it the air will be drawn in by the difference of pressure. If the inlets are of the same size as the fan area, the inlet velocity will be practically the same at all positions in the room; but the output will be reduced, for a velocity equal to that of the fan must then be given to the air both when coming in, and again when going out, and hence twice the energy is absorbed. Under these conditions the inlet velocity will be high, and the effect of outside wind therefore small.

* This figure is taken from the Second Report of the Departmental Committee on Ventilation of Factories [Cd. 3553] 1907.

If the openings are very large compared with the fan area, the inlet velocity will be small, the position of the inlets will be of more importance and the actual volume coming in at each one will be regulated by the direction and velocity of the outside wind. With large inlets on both sides of the room the general drift of the air will be settled by the prevailing wind. All the openings to windward will act as inlets, and the balance between the fan capacity and the inlet current will pass out at the openings to leeward. Under these conditions the natural ventilation may add considerably to that produced by the fans.

It has been suggested that considerable advantage might be derived by passing the air through water sprays, or over wet surfaces, as is done in some weaving sheds. It has, however, been borne in mind that in this respect the conditions in a spinning mill are entirely different, as owing to the spray from the flyers and the large wet surfaces the air in a spinning room already contains more moisture than it would contain if it entered fully saturated at the outside temperature.* The cooling effect depends essentially on the total amount of water evaporated, and whether the evaporation takes place before or after the air enters the room the effect is not widely different; the direct cooling due to the difference between the temperature of the water and that of the outside air is relatively unimportant.†

As we have seen above, the temperature of a spinning room depends essentially on the amount of ventilating air per unit of heat generated, and as the amount of heat generated is independent of the size of the room, and for similar goods is directly proportional to the total length of the frames employed, it is preferable to measure the ventilation in cubic feet per hour per unit length of frame, and not in changes of air per hour.

In modern mills the machinery is less crowded than in mills of older construction, and it will be found that a ventilating current of 2,000 cubic feet per hour per linear foot of frame corresponds to 20 changes of air per hour in an old mill, and about 16 in a mill of modern construction. There is no serious difficulty in obtaining 20 changes per hour in a spinning room, without involving large expenditure, and if the installation is well-planned draughts can be avoided. In fact, some preparing rooms have ventilating plants producing over 40 changes per hour.

The ideal method undoubtedly consists in using exhaust and plenum systems simultaneously, the former being arranged to remove the hot air as it arises from the troughs in a similar manner to that described on p. 91. A room ventilated in this manner is little affected by the direction or velocity of the prevailing wind, and a perfectly uniform distribution of air can be obtained. Further, as the room may be kept at atmospheric pressure, the opening or closing of the doors, windows, &c., will not cause changes in the air circulation or draughts. In many mills, however, such an arrangement, if designed to carry a sufficiently large volume of air, would be very expensive and inconvenient.

Good results may be obtained with less expenditure, and it may be of interest to outline some alternative schemes for producing a high rate of ventilation without entailing uncomfortable draughts. The diagrams are sketched out on the assumption that 2,000 cubic feet of air per linear foot of frame are required. In a mill of modern construction, such as represented in Figs. LVI. and LVII., this implies 12·5 changes of air per hour; in a mill overcrowded with machinery (see Figs. LVIII., LIX.), it implies 17·4 changes of air per hour.

In the first mill the desired result may be just attained by four 30-inch fans, as shown in Fig. LVI., while six 30-inch fans, as shown in Fig. LVII., give an ample margin. To give an inlet area of three times the fan area all the upper windows on the side opposite the fans require to be swung back by 11-inch and 16-inch in the two cases.

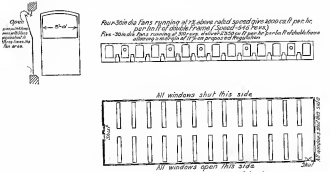

Fig. LVI.

Fig. LVI. shows a suitable disposition of fans and windows for a mill of modern construction. The arrangement is such as to provide with fans of average efficiency a ventilating volume of 2,000 cub. ft. per lin. foot of frame corresponding in this case to 12·5 changes per hour. The window openings provide an inlet area of three times the area of the fans.

* Thus, assume the outside temperature to be 60° F. and the thermometer readings in the mill 80° F. dry and 75° F. wet. The incoming air, if saturated, would contain 5·8, and the air in the room 8·3 grains of moisture.

† Thus if the temperature of the water is 50° F. and the temperature of the outside air 60° F. dry and 50° F. wet bulb, the cooling effect of the water would be $0{\cdot}075 \times 10 \times 0{\cdot}23 = 0{\cdot}17$ B.T.U. per cub. ft., whereas the cooling effect due to the evaporation, whether taking place in the room or outside, would be approximately $(8{\cdot}3 - 2{\cdot}9) \times \frac{1100}{7000} = 0{\cdot}85$ or five times as great.

In the second mill, two 30-inch fans are sufficient (*see* Fig. LVII.) and three 30-inch fans give an ample margin (*see* Fig. LIX., page 99). In these cases the upper window sashes require to be swung back by 8 inches and 12 inches respectively.

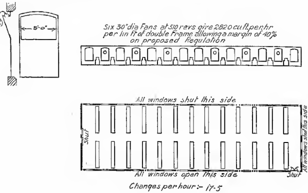

FIG. LVII.

a suitable disposition of fans and windows for a mill of modern construction.
's such as to provide with fans of average efficiency a ventilating volume 40 per cent. in excess

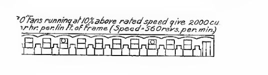

FIG. LVIII.

e disposition of fans and windows for a mill crowded with machinery and with
o provide with fans of average efficiency a ventilating volume of 2,000 cub. ft. per lin.
's case to 17·4 changes per hour. The window openings provide an inlet area of

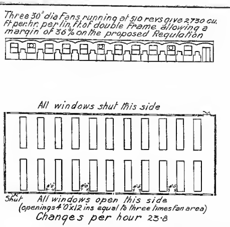

Fig. LIX.

Fig. LIX. shows a suitable disposition of fans and windows for a mill crowded with machinery and with small headroom. The arrangement is such as to provide, with fans of average efficiency, a ventilating volume 36 per cent. in excess of that in Fig. LVIII.

Construction of New Spinning Rooms

In the planning and construction of a mill much may be done to improve the conditions under which work will be carried out, and in the newer buildings many improvements have been introduced. It is therefore of importance to draw attention to some of the more important points, which may be summarised as follows.—

1. *Height of Room.*—Rooms of less than 11 feet in height are sometimes found in the older mills, while some rooms of modern construction are nearly 14 feet from floor to ceiling. Conspicuous advantages are gained by the extra height, which greatly improves the lighting in the centre of the room, and enables a rapid ventilation to be maintained without draughts reaching the spinners.
2. *Width of Rooms.*—This is essentially of importance in relation to the length of frame used. The very wide rooms which are found in Continental mills, however, are undoubtedly bad; for unless extremely lofty, rooms of more than 60 feet wide will be dark and difficult to ventilate. In a few of the best arranged mills the frames occupy no more than four-fifths of the width of the room, and thus leave a wide pass along the centre.
3. *Width of Stands.*—The most suitable arrangement appears to be obtained by allowing a width of about 6 feet from spindle to spindle. Wide stands add to the comfort of the workers and enable splash guards to be fitted wherever necessary.
4. *Window Arrangement.*—In many of the older mills the windows are narrow, and in a brick construction it is difficult to increase the window area beyond a certain extent. In modern ferro-concrete or steel frame structures, however, the window area may be as large as desired. The actual area will be determined in relation to the illumination required, and if the total width of the upper part of the windows are arranged to swing back by not less than 18 inches say, the openings will generally prove sufficient for ventilation purposes. It is desirable that all windows through which sunshine may find its way during working hours should be provided with blinds. For, although, as we have seen, solar radiation adds little to the temperature of a spinning room, direct sunshine is very uncomfortable for the workers. The blinds should be arranged in such a manner as not to impede the air circulation.
5. *Floors.*—In all new mills attention has been paid to the grading of the floors and to the selection of the material with which they are paved. The question is specially important where coarse spinning is carried out.
6. *Position of Spinning Room.*—It is, of course, preferable for the spinning room to be located between two relatively cool rooms, such as preparing or reeling rooms, but, as shown above, the heat carried away by the floor and ceiling of a spinning room is relatively small, and the position of the room is therefore not of primary importance.
7. *Machinery.*—Some advantage may be gained by electric driving. The question of the better thermal insulation of the troughs, is, however, far more important. Details of some experimental work in this direction have been given above but the question deserves further investigation.
8. *Ventilation.*—It has been shown that the temperature of the room *depends primarily* on the efficiency of the ventilation. It is therefore of great importance that adequate arrangements should be made for introducing a *sufficient quantity* of fresh air into the room in such a manner as to secure *even distribution* and absence of *draughts*.

In conclusion, it must be stated that modern mills in general show decided advances in general construction and arrangement. The staircases are usually wide and well lighted; cloak rooms are provided on each floor, and, apart from strict legal requirements, much consideration is shown for the comfort of the operatives.

APPENDIX XI.

Effects of (a) Automatic Steam Valves and (b) Increased Ventilation on the Temperature of Wet Spinning Rooms.

(a) The following table has been supplied by a firm who have recently adopted automatic valves for the steam supply to the spinning troughs, whereby the temperature of the troughs can be kept almost constant.

Average of Temperatures at 11 a.m. in a Spinning Room during a Period when the Steam Pipes were provided with Automatic Valves, compared with a similar Period before these were adopted.

Year	Average Temperatures.							
	November		December		January		3 months	
	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.
1912–13 (without valves)	81·9	78·4	82·8	79·7	82·2	78·9	82·3	78·9
1913–14 (with valves)	78·3	74·7	77·4	73·8	77·3	74·1	77·6	74·2
Difference	*3·6*	*3·7*	*5·4*	*5·9*	*4·9*	*4·8*	*4·7*	*4·7*

(b) The following table, also supplied by the firm concerned, shows the effect of ventilation upon temperature

Average of Temperatures at 11 a.m. in a Wet Spinning Room with varying Degrees of Ventilation.

Period.	Changes of air per hour.	Average Temperatures.							
		November.		December.		January.		3 months.	
		Dry.	Wet.	Dry.	Wet.	Dry.	Wet.	Dry.	Wet.
Period A (1912–13)	8	79·0	74·0	79·4	74·0	79·1	74·1	79·2	74·0
Period B (1913–14)	13	75·3	72·2	75·0	72·1	75·4	72·4	75·2	72·2
Difference	—	*3·7*	*1·8*	*4·4*	*1·9*	*3·7*	*1·7*	*4·0*	*1·8*

Size of spinning room, 234 ft. 6 ins. × 47 ft. 3 ins × 12 ft. 5 ins. Cubic capacity, 140,643 cubic ft., 26 windows 4 ft. 5 ins. wide, with air pane openings at top up to 16 ins. at 12 ft. from floor. If air pane is open 2¼ ins. at top, the area of air inlets is 21 square feet. 51½ spinning frames working.

Period A. Four 24-in. fans in use discharging 18,844 cubic ft. per minute corresponding to 8 changes of air per hour.

Period B. Four 24-in. and four 18-in. fans in use discharging 31,564 cubic ft. corresponding to 13 changes of air per hour.

APPENDIX XII.

Results of Tests carried out in Weaving Factories to show Effects of different Degrees of Humidity on Weaving.

These tests were carried out by the Committee and may be divided into three groups.

1. The earliest method consisted in simply counting the breaks occurring in a given time on looms weaving cloth of various kinds—

(a) under ordinary weaving conditions, and
(b) after all artificial humidity had been turned off.

The results may be summarised as follows :—

TABLE A.

Description of Cloth: Sets (Hundreds). (1)	Yarn (Leas). (2)	With Humidity: Duration of Test (Mins.) (3)	Conditions: Average Temperature: Dry (4)	Wet (5)	Relative Humidity. (6)	Breaks per Hour (7)	Without Humidity: Duration of Test (Mins.). (8)	Conditions: Average Temperature: Dry (9)	Wet (10)	Relative Humidity (11)	Breaks per Hour. (12)	*Increase in Breaks per Hour* (13)
18/19	75/110	60	74·8	72·7	88	7	120	68·9	65·0	78	12	*5*
"	"	"	"	"	"	6	"	"	"	"	28	*22*
"	"	"	"	"	"	11	"	"	"	"	36	*25*
17/18	80/120	"	"	"	"	15	"	"	"	"	16	*1*
"	"	"	"	"	"	9	"	"	"	"	12½	*3½*
"	"	"	"	"	"	16	"	"	"	"	29	*13*
16/17	70/110	"	"	"	"	10	"	"	"	"	15½	*5½*
14/14½	75/110	"	"	"	"	12	"	"	"	"	45	*33*

In this series of tests the weights regulating the tension of the warp threads were adjusted so as to keep the width as nearly constant as possible.

2. The number of breaks per hour is, roughly speaking, a measure of the actual labour involved, but does not indicate the effect on the quantity of cloth woven, since the actual time during which the loom is working is not the same for the two tests, but diminishes as the number of breaks increases. In the next series of tests the actual lengths of cloth woven under the two conditions were measured by stitching or pinning a piece of tape on to the cloth and allowing it to be wound up with the cloth on to the cloth beam. The time and other details were marked at short intervals on the tapes, which were returned by the manufacturers when the beam was eventually finished. Very useful information has been obtained in this way as is shown by the following table :—

TABLE B.

Description of Cloth woven: Set (Hundreds). (1)	Yarn (Leas). (2)	With Humidity: Duration of Test. (3)	Average Conditions: Temperature: Dry Bulb. (4)	Wet Bulb. (5)	Relative Humidity. (6)	Length woven per Hour (Yards). (7)	Breaks per Yard. (8)	Without Humidity: Duration of Test. (9)	Average Conditions: Temperature: Dry Bulb. (10)	Wet Bulb. (11)	Relative Humidity. (12)	Length woven per Hour (Yards). (13)	Breaks per Yard. (14)	*Decrease in Length woven (Yards).* (15)	*Increase in Breaks per Yard.* (16)
19/20 B	80/120	60	79·0	77·5	93	2·18	1·4	120	80·8	76·3	78	2·06	2·9	*0·12*	*1·5*
18/18 G	95/150	"	"	"	"	2·15	0·9	"	"	"	"	1·73	4·8	*0·45*	*3·0*
18/18 B	75/110	"	"	"	"	2·34	—	"	"	"	"	1·97	7·0	*0·37*	—
"	"	"	"	"	"	2·08	3·8	"	"	"	"	1·91	8·8	*0·17*	*5·0*
18/17 B	75/100	"	"	"	"	2·56	4·3	"	"	"	"	2·65	5·7	*−0·09*	*1·4*
15/17	70/90	"	"	"	"	2·30	4·3	"	"	"	"	2·36	3·2	*−0·06*	*−0·9*
15/16 G	"	"	"	"	"	3·68	2·0	"	"	"	"	2·80	3·0	*1·38*	*1·2*
"	"	"	"	"	"	3·00	1·3	"	"	"	"	2·68	0·8	*0·32*	*1·7*
14/14 B	80/60	"	"	"	"	3·06	1·3	"	"	"	"	3·08	1·5	*−0·02*	*−0·5*
"	"	"	"	"	"	2·96	1·3	"	"	"	"	2·96	0·3	*0·00*	*0·2*
13/13½	70/100	"	"	"	"	2·9	—	"	"	"	"	3·0	2·0	*−0·1*	*−2·5*
12/12	65/90	"	"	"	"	3·1	4·5	"	"	"	"	3·2	4·7	*−0·1*	*4·0*
14/15 B	—	"	79·0	75·4	82	3·0	0·7	"	78·8	72·8	71	3·1	—	*−0·1*	—
12/13	—	"	"	"	"	3·0	0·7	"	"	"	"	3·0	—	*0·00*	—
15/8	—	"	"	"	"	4·4	1·1	"	"	"	"	5·6*	—	*−1·2**	—
11/8	—	"	"	"	"	5·1	—	"	"	"	"	6·2*	—	*−1·1**	—
9/8½	—	"	"	"	"	5·6	0·0	"	"	"	"	5·7	—	*−0·1*	—
10½/7	—	"	"	"	"	5·1	—	"	"	"	"	5·9	—	*−0·8*	—
7/7	—	"	"	"	"	4·5	—	"	"	"	"	6·7*	—	*−2·2**	—
6/7	—	"	"	"	"	5·9	—	"	"	"	"	7·0*	—	*−1·1**	—
8/6½	—	"	"	"	"	6·7	0·1	"	"	"	"	6·5	—	*0·2*	—
5/4½	—	"	"	"	"	9·9	0·2	"	"	"	"	9·5	—	*0·4*	—

* It is probable that in these cases a new beam had been put in the loom and that cloth with a different set was being woven.

NOTE.—Col. (15). The minus sign (−) indicates increases. Col. (16). The minus sign (−) indicates decreases.

(3) A third series of tests was undertaken on looms specially removed from the weaving shed and placed in a separate enclosure where the temperature and humidity could be varied at will.

The results of two tests are shown by the following table :—

TABLE C.

Description of Cloth woven.		With Humidity							Without Humidity.								
Set (Hundreds).	Yarn (Leas).	Duration of Test.	Average Conditions. Temperature. Dry Bulb.	Average Conditions. Temperature. Wet Bulb.	Average Conditions. Relative Humidity.	Length woven per Hour (Yards).	Breaks per Yard.	Maximum Width (Inches).	Duration of Test.	Average Conditions. Temperature. Dry Bulb.	Average Conditions. Temperature. Wet Bulb.	Average Conditions. Relative Humidity.	Length woven per Hour (Yards).	Breaks per Yard.	Maximum Width (Inches).	*Decrease in Length woven (Yards)*	*Increase in Breaks per Yard.*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
20/20	120/160	42	78·0	76·0	89	1·82	10·4	44	90	77·5	68·5	66	1·37	21·0	44½*	*0·45*	*10·6*
„ †	„	*33*	*82·1*	*81·1*	*95*	*2·35*	*0*	*44*	89	77·5	70·1	65	1·31	19·0	44¾‡	*1·04*	*19·0*
„ †	„	*102*	*76·1*	*74·1*	*89*	*2·10*	—	—	—	—	—	—	—	—	—	—	—
„ †	„	*105*	„	„	„	*2·10*	*3·0*	—	—	—	—	—	—	—	—		—
„ †	„	*117*	„	„	„	*1·6*	*0·2*	—	—	—	—	—	—	—	—	—	—
„ †	„	*65*	„	„	„	*2·15*	*1·0*	—	—	—	—	—	—	—	—		—
19/19	110/150	51	83·8	81·8	90	2·06	4·6	46⅜	91	77·6	73·6	79	1·57	21·2	46¼‡	*0·49*	*16·6*

* Extra weight put on beam. † These looms were running in the shed under ordinary conditions. ‡ No extra weight put on beam.

Another test was carried out on much the same plan for a finer cambric.

As before, a loom specially intended for experimental purposes was placed in a separate enclosure where the humidity could be rapidly varied within wide limits.

The work on this loom was compared with that on a loom in the shed weaving identical cloth under the best possible conditions. The cloth woven was plain cambric; $24^{00} \times 24$; warp yarn, 150's; weft yarn, 200's.

At the commencement of the experiment both looms were working with a humidity of 89 per cent.

All steam was turned off from the experimental enclosure and the humidity rapidly fell to 65 per cent. After the weaving had been continued at this humidity for two hours, steam was turned on again and the original conditions reverted to.

Observations.—The measurements taken at frequent intervals were :—

(*a*) The readings of the wet and dry bulb thermometers.
(*b*) The length of cloth woven.

The time of each breakage of a warp thread was also noted.

If the number of breaks alone had been counted and no account taken of the amount of cloth woven, the results would have been misleading, for under the worst conditions the loom being stopped for considerable periods, the number of breakages per hour decreases.

From these results the following table has been prepared. It includes the average humidity during the period considered, also the units of length woven per hour, and number of breaks per unit of length woven.

The former determines the weaver's wage, the latter is a measure of the amount of labour involved.

A high number of breakages per unit of length also implies unsatisfactory cloth.

Results.—It will be seen that the immediate effect of turning off the steam is to increase the breakages without reducing the rate of production.

Later the production is seriously affected.

Finally, when steam is turned on again the weaving returns rapidly to normal conditions.

The effect of the reduction in humidity can be gauged either by comparing the initial and final condition with the second and third periods (when steam was off) or by comparing the work done by the experimental loom with the average work done by another loom running under constant and normal conditions.

TABLE D.

—	Duration of Test (Mins.).	Average Humidity.	Units of Length (per Hour).	Breaks per Unit of Length.
1st period, steam on	34	89·5	1·39	8
2nd period, steam off	44	67·3	1·53	12
2nd period, steam off (later period)	85	63·0	0·35	28
4th period, steam on again	80	88·5	1·56	4
Average for a loom weaving similar cloth under normal conditions.	—	90·5	1·50	5

Finally, a series of tests was carried out by a manufacturer of fine cambrics, and the results with the inferences drawn by him are as follows :—

TABLE E.

Averages of Groups of Ten Tests (eliminating abnormal ones) in order of (*a*) Temperature, (*b*) Difference between Dry and Wet Bulb Temperature, (*c*) Warp Breakages in Unit Length of Cloth woven, and (*d*) Time occupied in weaving Unit Length.

On Basis of Temperature.				On Basis of Difference between Dry and Wet Bulb Temperatures				On Basis of Warp Breakages.				On Basis of Time occupied.			
Wet Bulb Temperature	Difference between Dry and Wet Bulb Temperatures	Warp Breakages	Time occupied.	Wet Bulb Temperature	Difference between Dry and Wet Bulb Temperatures.	Warp Breakages.	Time occupied.	Wet Bulb Temperature	Difference between Dry and Wet Bulb Temperatures	Warp Breakages.	Time occupied	Wet Bulb Temperature.	Difference between Dry and Wet Bulb Temperatures	Warp Breakages	Time occupied.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
61·6	1·5	11·3	52·0	66·0	1·1	6·3	47·5	68·1	1·36	3·7	43	68·9	1·4	4·7	40·7
64·0	1·7	11·1	54·0	66·0	1·4	7·4	43·4	66·1	1·52	5·6	44	66·4	1·4	6·0	45·0
65·7	1·5	7·3	47·6	67·0	1·6	6·8	46·1	67·3	1·57	7·5	49	65·8	1·5	7·1	46·9
68·5	1·6	7·6	46·0	64·6	1·7	9·8	50·2	66·7	1·80	10·0	52	63·7	1·7	11·8	56·5
72·0	1·7	6·3	42·0	68·0	2·2	13·3	60·0	63·5	1·90	16·6	61	63·9	2·2	18·5	68·0

NOTE.—Columns (1) to (4) show that as the temperature increases warp breakages and time occupied decrease.

Columns (5) to (8) show that as the difference between the wet and dry bulb temperatures increases, the warp breakages and time occupied increase.

Columns (9) to (12) show that as warp breakages increase, the difference between the wet and dry bulb temperature increases, and the temperature decreases.

Columns (13) to (16) show that as the time occupied increases the temperature decreases, whilst the difference between wet and dry bulb temperatures and warp breakages increases.

The general conclusions to be drawn from these tests is that the weaving of fine cambrics is detrimentally affected at all temperatures by a less degree of humidity than that corresponding to a difference between the wet and dry bulb temperatures of two degrees. The effects show themselves in the lessened production, the increase in breakages with consequent deterioration of the cloth woven, and (unless additional weights are put on the beam still further increasing the breakages) in the greater width of the cloth.

For medium and coarse goods the detrimental effect is much less marked and is often entirely absent. In these instances, also, however, it was stated by the manufacturers concerned that the cloth woven was seriously damaged from a marketable standpoint.

APPENDIX XIII

RETURN SHOWING WIDTH OF STANDS IN 110 SPINNING ROOMS WITH AND WITHOUT SPLASH-GUARDS

Width of Stand (Spindle to Spindle)	Pitch of Frame, or Distance between two adjacent Spindles (Inches)																							
	Stands without Splash guards.								Stands with Splash guards on one side								Stands with Splash guards on both sides							
	1¾ and less	1⅞	2	2⅛	2¼	2½	3	Over 3	1¾ and less	1⅞	2	2⅛	2¼	2½	3	Over 3	1¾ and less	1⅞	2	2⅛	2¼	2½	3	Over 3
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)
Feet																								
< 3	—	5	4	3	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3–3¼	—	—	8	8	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
3¼–3½	—	1	12	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3½–3¾	—	4	7	9	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
3¾–4	—	8	17	8	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	3	8	8	1	—
4–4¼	8	53	34	16	3	1	—	—	—	—	—	1	—	2	1	—	—	1	18	15	12	8	1	1
4¼–4½	24	78	264	75	53	3	—	—	—	—	1	1	3	15	3	1	—	—	9	15	7	14	7	1
4½–4¾	1	49	146	85	85	—	—	—	—	—	1	3	2	3	—	—	—	1	5	23	30	18	1	15
4¾–5	5	59	355	221	124	—	—	—	—	1	1	1	3	7	—	2	—	11	44	56	44	43	13	12
5–5¼	48	149	278	99	91	2	—	—	—	—	—	3	—	3	2	—	—	5	43	13	31	42	13	10
5¼–5½	—	6	3	5	10	2	—	—	—	—	—	2	—	—	—	—	—	6	25	18	4	2	—	3
5½–5¾	—	5	110	37	38	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	4	2	—	3
5¾–6	—	20	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	8	10	1	—
> 6	2	2	25	18	8	—	—	—	—	—	1	3	2	3	3	—	—	—	2	5	8	5	—	19
Total	88	422	1,215	584	406	11	—	—	—	1	4	18	9	38	12	7	—	24	146	160	156	148	44	51

Col (1) < 3 = less than 3 feet
3–3¼ = 3 feet or more but less than 3¼ feet, &c.
Cols (2) to (25) Frames of intermediate pitches are included amongst the next lowest Thus 2⅜ inch pitch frames are included in cols (6) (14) (22)

APPENDIX XIV.

LIST OF FACTORIES VISITED.

No.	Date	Name of Firm.	Address.	Spinning or Weaving.
1	23.7.12	J. & T. M. Greeves, Ltd.	Forth River Mills, Belfast	S.
2	,,	Lurgan Weaving Co., Ltd.	Lurgan	W.
3	,,	Johnston, Allen & Co.	Woodville, Factory, Lurgan	W
4	,,	James Malcolm, Ltd	Lurgan Weaving Factory, Lurgan	W.
5	12.9.12	Portadown Weaving Co., Ltd	Armagh Factory, Portadown	W
6	,,	Spence, Bryson & Co., Ltd.	Clonavon Factory, Portadown	W.
7	17.9.12	York Street Flax Spinning Co., Ltd.	York Street Mills, Belfast	S. & W.
8	18.9.12	Smithfield Weaving Co., Ltd	Smithfield Factory, Belfast	W.
9	19.9.12	Jaffe Spinning Co., Ltd	Newtownards Road, Belfast	S.
10	2.10.12	J. H. Crossley & Sons	Deanclough Mills, Halifax	W.
11	,,	Robert Pickles	Cairo Mill, Burnley	W.
12	3.10.12	Brookside Weaving Co., Ltd	Charles Street, Darwen	W
13	4.10.12	Jonathan Harris & Sons, Ltd.	Derwent Mills, Cockermouth	W.
14	,,	Ainsworth & Sons, Ltd.	Cleator Mills, Cleator Moor	S
15	19.10.12	John Shaw Brown & Sons, Ltd.	Ardoyne Factory, Belfast	W.
16	21.10.12	Edward Gribbon and Sons	Coleraine	W
17	,,	Balnamore Spinning Co., Ltd.	Balnamore, Ballymoney	S.
18	,,	Braid Water Spinning Co., Ltd.	Ballymena	S.
19	,,	J. H. & G. Bellis	Braid River Factory, Ballymena	W.
20	,,	Phœnix Weaving Co.	Phœnix Factory, Ballymena	W
21	22.10.12	Thos. Adair & Co.	Greenvale Mills, Cookstown	S.
22	,,	Thos. Adair & Co.	Gortalowney, Cookstown	W.
23	,,	Hale, Martin & Co., Ltd	Dungannon	S.
24	,,	Acheson & Smith	Castlecaulfield, Donaghmore	W.
25	23.10.12	Gunning & Campbells, Ltd.	North Howard Street, Belfast	S
26	,,	Doagh Flax Spinning Co., Ltd.	Doagh	S.
27	,,	Cogry Flax Spinning Co., Ltd.	Cogry Mills, Doagh	S.
28	24.10.12	William Barbour & Sons, Ltd	Hilden Works, Lisburn	S.
29	,,	Robert Stewart & Sons, Ltd	Lisburn Mills, Lisburn	S.
30	,,	Island Spinning Co., Ltd.	Island Mills, Lisburn	S. & W
31	,,	Lambeg Weaving Co., Ltd.	Lambeg, Lisburn	W.
32	25.10.12	New Northern Spinning Co., Ltd.	Falls Road, Belfast	S. & W.
33	,,	Ulster Spinning Co., Ltd.	Falls Road, Belfast	S. & W.
34	,,	Ulster Spinning Co., Ltd.	Linfield Mill, Belfast	S.
35	,,	Ulster Weaving Co., Ltd.	Linfield Factory, Belfast	W.
36	,,	John Andrews & Co., Ltd.	Comber	S.
37	2.4.13	Brookfield Linen Co., Ltd.	Agnes Street Factory, Belfast	W.
38	13.5.13	Crawford Bros., Ltd	Barrmill, Beith, Scotland	S.
39	,,	W. & J. Knox, Ltd	Kilbirnie, Scotland	S.
40	,,	Finlayson, Bousfield & Co.	Johnstone, Scotland	S.
41	26.5.13	Herdmans, Ltd.	Sion Mills, Co. Tyrone	S.
42	27.5.13	James Murland, Ltd.	Annsborough, Co. Down	S. & W.
43	,,	John Martin & Co., Ltd.	Shrigley Mills, Killyleigh	S.
44	,,	Thomas Sinton & Sons	Killyleigh Mills, Killyleigh	S.
45	28.5.13	Roan Spinning Co., Ltd.	Coalisland	S.
46	30.5.13	Thomas Sinton	Laurel Vale, Tandragee	W.
47	,,	Thomas Sinton	Spinning Mill, Tandragee	S.
48	,,	Bessbrook Spinning Co., Ltd.	Bessbrook	S. & W.
49	23.7.13	Greenmount Spinning Co.	Harold's Cross, Dublin	W.
50	26.7.13	Belfast Flax & Jute Co., Ltd.	Owen O'Cork Mills, Belfast	S.
51	,,	Morrison & Metcalfe	Grove Mill, Belfast	S.
52	22.9.13	Société Anonyme de la Lys	Ghent, Belgium	S.
53	23.9.13	Société Anonyme Linière Gantoise	Ghent, Belgium	S.
54	,,	Société Anonyme Linière St Sauveur	Ghent, Belgium	S.

APPENDIX XV.

List of Witnesses examined.

No.	Name	Description.
1	Sydney Erant	H.M. Inspector of Factories for the Belfast District.
2	——	Power Loom Tenter.
3	Mary Galway	Secretary to the Textile Operatives Society of Ireland.
4–10	——	7 Power Loom Weavers.
11	James Alexander Lindsay, M.D., F.R.C.P.	Professor of Medicine, Queen's University, Belfast.
12	Arthur Thomas Herdman[2]	Immediate Past President of the Power Loom Manufacturers' Association.
13	John Elder MacIlwaine, M.D., B.Sc., D.P.H.	Certifying Surgeon.
14	Michael Corbett Andrews[2]	Works Manager, John Shaw Brown and Sons, Ltd.
15	James Henry Hamilton[1]	Managing Director, Whitehouse Spinning Company.
16	John Barbour Morrison[1]	Manager, Wolfhill Spinning Co., and Partner in Morrison & Metcalfe.
17	Alfred Ernest Adams[1]	Manager, Ulster Spinning Co., Ltd., Linfield Mill.
18	T. Jackson Greeves[2]	Managing Director, Portadown Weaving Co., Ltd.
19	Thomas H. Spence[2]	Director, Spence, Bryson & Co., Ltd.
20	George Elliott Lutton[2]	Manager, Spence, Bryson & Co., Ltd.
21	James Glasgow Crawford	Managing Director, York Street Spinning Co., Ltd.
22–29	——	8 Power Loom Weavers.
30	Edward T. Addy[2]	Manager, Brookfield Linen Co., Ltd., Agnes Street Factory.
31	Daniel Drennan[2]	Manager, Lurgan Weaving Co., Ltd.
32	Joseph Leathem[2]	Inside Manager, Johnson, Allen & Co., Ltd.
33–36	——	4 Operative Spinners.
37	Hilda Martindale	H.M. Senior Lady Inspector of Factories.
38	William Williams	H.M. Superintending Inspector of Factories.
39–42	——[3]	4 Power Loom Weavers.
43	James Macartney[2]	Director, Falls Flax Spinning Co., Ltd.
44	Elias B. Purdon, M.B., C.M., L.R.C.S. Ed.	Certifying Surgeon.
45	William Burns, L.R.C.S., D.P.H.	Dispensary Medical Officer.
46	William E. Gordon	Manager, Herdmans, Ltd.
47	Ambrose Ricardo	Director, Herdmans, Ltd.
48	William John MacDowell	Secretary, Power Loom Tenters' Trade Union of Ireland.
49	Leonard Hill, M.B., F.R.S.	Professor of Physiology, London University.
50	William J. Brabazon	Manager, Rose Bank Weaving Co., Ltd.
51	Andrew McAlister	Manager, Parkside Weaving Co., Ltd.
52	Emily J. Slocock	H.M. Senior Lady Inspector of Factories.
53–54	——	2 Power Loom Weavers nominated by the Portadown Weaving Co., Ltd.
55	John Miller Andrews	Managing Director, John Andrews & Co., Ltd., Comber.
56–62	——	7 Operative Spinners and Spinning Foremen (Scotland).
63	Maurice Sutcliffe	Director of the Sutcliffe Ventilating and Drying Co., Ltd., Ventilating Engineers.
65	Walter Yates	Managing Director of Matthews and Yates, Ltd., Ventilating Engineers.

[1] Nominated by the Flax Spinners' Association.
[2] Nominated by the Power Loom Manufacturers' Association.
[3] Nominated by the Ulster Weavers' and Winders' Trade Union.